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Proceedings of the Seminar on Small Airplane Crashworthiness Research and Development

March 9, 1988
Ottawa, Ontario

Prepared for

Transportation Development Centre
Policy and Coordination Group
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16. Abstract

This report contains the papers presented at the Seminar on Small Airplane Crashworthiness Research and Development held in Ottawa on March 9, 1988, and sponsored by the Transportation Development Centre (TDC). Speakers represented the Canadian Aviation Safety Board, the U.S. National Transportation Safety Board, National Aeronautics and Space Administration, and the Federal Aviation Administration. The subject matter of the presentations reviewed the current status of North American research and development in small airplane crashworthiness.

Also included in the report are the afternoon proceedings, which comprised short introductory comments from each of the panelists and open discussions. The subject matter was the future focus of Canadian research and development and regulatory activity in small airplane crashworthiness.

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16. Résumé

Ce document regroupe les communications présentées à l'occasion du Colloque sur la R&D en résistance à l'écrasement des petits aéronefs, organisé par le Centre de développement des transports (CDT) à Ottawa, le 9 mars 1988. Les conférenciers représentaient le Bureau canadien de la sécurité aérienne et les trois organismes américains suivants : National Transportation Safety Board, National Aeronautics and Space Administration et Federal Aviation Administration. Les communications présentées faisaient le point sur l'avancement des travaux de R&D nord-américains dans le domaine concerné.

Ce document présente également le procès-verbal des séances de l'après-midi : remarques d'introduction par chacun des panélistes et débats libres. Les sujets traités étaient l'orientation future des travaux de R&D dans ce domaine au Canada et la réglementation en matiere de résistance à l'écrasement des petits aéronefs.

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FOREWORD

The Seminar on Small Airplane Crashworthiness Research and Development was held in the Government Conference Centre in Ottawa, Ontario, on March 9, 1988. The seminar was sponsored by the Transportation Development Centre (TDC) of the Policy and Coordination Group of Transport Canada.

This document is a transcription of the proceedings and only some illustrations are reproduced.

TDC expresses its thanks to all the seminar participants. Particular thanks are due to the speakers from industry and government whose papers are reproduced in these Proceedings, to the moderator, Mr. James Torck and the panelists who led discussion in the afternoon sessions.

SUMMARY

1. INTRODUCTION

The Seminar on Small Airplane Crashworthiness Research and Development was held in the Government Conference Centre in Ottawa, Ontario, on March 9, 1988. The seminar was sponsored by the Transportation Development Centre (TDC) of the Policy and Coordination Group of Transport Canada.

The primary objectives of the seminar were to review the status of North American research and development in the field of small airplane crashworthiness, and to identify those areas which Canada could make a meaningful contribution.

2. PROCEEDINGS

The seminar was opened by Mr. Claude La France, Assistant Deputy Minister of Aviation, Transport Canada. He welcomed the many expert speakers and participants. Mr. James Torck, Director of Airworthiness, Transport Canada also had opening remarks. He gave a short history of the development of the issue of small aeroplane crashworthiness and Transport Canada's role in the R&D process. Mr. Torck summarized the primary objective of the Seminar achieving a first step in developing a coordinated R&D program between Canadian government, industry and university interests, and between Canada and the United States.

Mr. Bill McLaren, of TDC in Montreal, introduced each of the speakers in the morning session. Four speakers representing various agencies in Canada and the U.S. made presentations (summarized on the following pages). The Canadian Aviation Safety Board (CASB), the National Transportation Safety Board (NTSB), and the Federal Aviation Administration (FAA) presented papers at the morning session. As well, two films were provided by the National Aeronautics and Space Administration and presented by Dr. Chandler from the Civil Aviation Medical Institute (CAMI) of the FAA.

In the afternoon, Mr. James Torck acted as a moderator in a discussion panel of six experts representing CASB, FAA, deHavilland Canada, University of Toronto, Transport Canada and the National Aeronautical Establishment of the National Research Council. Each panelist was given a few minutes to introduce their point of view and an open discussion followed. Panelists from Transport Canada and the National Research Council provided a synopsis of where research in Canada is heading.

"Small Airplane Accident History in Canada," William Tucker, Director Safety Programs, Canadian Aviation Safety Board

There has been a decrease in the number of accidents per 100,000 hours flown from 19 in 1976 to 15 in 1986. Fatal accidents have decreased over this same period from 2.4 per 100,000 hours to 1.5. However, fatal accidents, as a percentage of total accidents have remained essentially constant. The implication is that survivability of crashworthiness has not really improved.

Severity of injury and number of fatalities are generally correlated with the severity of accidents, as indicated by the degree of damage and angle of impact. However, in individual accidents, there are many exceptions to this general rule where fatalities have occurred in relatively minor accidents or where the severe crashes have been survived. There are also many cases where the initial impact is survivable but death has occurred due to secondary impact, post-crash fire, etc. Survivability appears to be improved when the deceleration is more gradual as in impacting trees or water as opposed to mountains.

Use of shoulder harnesses is very important. The number of small aircraft equipped with shoulder harnesses has increased from 32% to 50% over the decade; still, only 75 to 80% of occupants that have them, use them. The studies indicate that fatalities run 60% higher without shoulder harnesses and that 28% of fatalities could be prevented by their use. Similarly, 90% of injuries would be less severe. The CASB has recommended that Transport Canada require shoulder harnesses in all commercial aircraft and strongly encourage their installation in private aircraft.

There are some additional areas that satisfy airworthiness requirements but do not consider crashworthiness; examples are propeller blade separation on impact and ease of door unlatching for escape following a crash.

The author suggests that focussing crashworthiness research on the most glaring examples could substantially improve survivability

"General Aviation Crashworthiness Project Findings: Summary Report of the National Transportation Safety Board," Gerrit Walhout, Senior Investigator, NTSB

Crashworthiness is defined as the ability of the airplane to protect its occupants from injury after its airworthiness has been compromised through one or more of a combination of mechanical, environmental, or human factors. Three important factors affect crashworthiness: airframe strength; occupant tie-down capability; and energy management. (Fire after impact is a further survivability issue.)

The author outlined the history of crashworthiness research from the 1940's to the Bureau of Safety of the Civil Aeronautics Board's recommendations of 1970 to the FAA. These dealt with shoulder harnesses, use of energy-absorbing materials in structures, dynamic testing, strength of seats and fuel system design. Little action was taken to implement recommendations due to institutional factors.

In 1980, the NTSB initiated a multi-year research program to encourage upgrading of occupant protection design standards. One approach was a statistically significant analysis of a large number of accidents and a second was an in-depth analysis of a small number of selected accidents; both aimed at defining the survivability margin.

This envelope was found to extend from a 75 knot speed of impact at zero degrees angle of impact to 45 knots at 90°. The upper limit of survival capability was found to be: for the longitudinal direction, 30 to 35 G's and 60 to 70 feet per second for acceleration and velocity changes respectively; for the vertical direction, the respective limits were 25 to 30 G's and 50 to 60 feet per second.

Both analyses produced similar findings, respectively:

	Broad Sample	Indepth Analysis
- fatality injured who would have survived with shoulder harness	75%	65%
- seriously injured who would have benefitted from shoulder harness	88%	77%
- seriously injured who would have benefitted from energy-absorbing seat	34%	24%

The most dramatic crashworthiness benefits derive from use of shoulder harnesses. Energy-absorbing seats only reduce fatalities by 2% but can reduce crippling spinal injuries by 34% (this is also a function of occupant mass).

The General Aviation Safety Panel recommended improved design requirements which could be met without excessive design penalties and cost. The NTSB analyses suggest that these should be viewed as minimum occupant protection design standards.

"General Aviation Seat and Restraint Systems: Performance Criteria and Dynamic Test Methodology," Richard Chandler, Supervisor Protection and Survival Research Laboratory, FAA Civil Aeromedical Institute

The laboratory, with a staff of 18, works in three areas:

1. facility development for low cost dynamic testing;
2. cooperate testing programs with industry and other agencies; and
3. developing test methods.

Cooperative testing had to overcome a defensive attitude in industry due to product litigation but programs have now been carried out with Beech, Piper, Cessna and Boeing-Vertol. In 1984, the laboratory was involved with development of test conditions leading to the General Aviation Safety Panel (GASP) recommendations.

Dynamic testing up to 30G impact levels has been carried out. Most injuries, however, are from secondary impact, i.e. impacts with the interior of the aircraft. A 1982 program with Cessna resulted in the energy-absorbing integrated seat restraint system for the new Caravan aircraft. This, with two similar programs, contributed to the GASP work. The principal results, achieved in less that a year and with a consensus within a diverse group, were in these areas:

- dynamic tests, up to 26 G's forward including lateral yaw and up to 16 G's vertically;
- floor deformation considerations as part of the test procedures;
- injury criteria including head, chest and spinal compression criteria;
- lap belts and shoulder harness position on the body specification;
- structural integrity of seat restraint systems developed dynamically that can now be applied statically; and
- flight/ground operational loads with a 215 lb. occupant (rather than 170 lbs.)

The results have now been applied in new information available for improved seat-restraint systems including advisory circulars, static and dynamic test procedures and an SAE Standard (8043) adopted as a TSO.

There is still difficult work to do in several areas:

- need for low cost aftermarket restraint system kits;
- non-destructive test for the fittings for such systems;
- inspection techniques, especially for non-metallic components such as webbing;
- low cost replacements for seat pans; and
- a test procedures for emergency locking retractors.

A final issue concerns side-facing seats which are still permitted but for which good restraint systems cannot be developed.

"General Aviation Fuel System: Crash Dynamics," Stephen Soltis, National Resource Specialist, FAA

The 1982 GASP initiative focussed on two areas for improved crash tolerance: namely, seat strength/occupant protection and fuel spillage/post-crash fires. The two areas involved in different technologies and so GASP-2 was formed in 1984 to more thoroughly address the latter. GASP-2 identified: frequency of fuel spillage and post-crash fires; frequency of injuries and fatalities; and sources of fuel spillage and potential ignition sources.

Of 121 survivable accidents, fuel spilled in 96 (79%); 78 of these spills were from the fuel tanks. There were five fatal post-crash fires. A study was undertaken of crash resistant fuel tanks (bladders). A first consideration was fuel volume reduction. It was found to be 8% to 14% depending on bladder cell thickness and a further 6 to 8% for fuel cavity liners for typical GA airfoil thickness ratios of 16%; this is as high as 20 to 45% for thinner wings of 12 to 13% ratio where the fuel cavity encompasses most of the available wing volume. There is also a weight penalty in the range of 1 to 3% of aircraft gross weight. The resultant reduction of aircraft range could be 8 to 14%.

A more selective approach is to install fuel cell bladders in accessible areas where ignition sources exist. The dominant aircraft included in the study were the thicker air foil type with cells or tanks; a marked increase in wet wing configurations may change the occurrence of fuel spillage and ignition sources found in the GASP-2 analysis.

The GASP-2 panel also made recommendations in 1987 for all GA airplanes of less than ten passengers concerning: fuel spillage at junctures of lines and equipment (eight ounces maximum); crash resistant tanks including means to reduce fuel spill and means other than bladders; and advisory circular based on the MIL specification with some modifications.

SOMMAIRE

1. INTRODUCTION

La recherche et le développement sur la résistance à l'écrasement des petits avions a été le thème du colloque qui s'est tenu au Centre de conférences du gouvernement du Canada à Ottawa (Ontario) le 9 mars 1988, organisé par le Centre de développement des transports du Groupe des politiques et de la coordination de Transports Canada.

Le but principal de ce colloque a été de faire le point sur les travaux de R&D en Amérique du Nord dans le domaine concerné et de mettre en évidence les secteurs où l'apport du Canada pourrait être significatif.

2. ACTES DU COLLOQUE

Ouvrant le colloque, M. Claude La France, sous-ministre adjoint, Aviation, Transports Canada, a souhaité la bienvenue aux nombreux participants et conférenciers. Il a été suivi de M. James Torck, directeur du service de la navigabilité, Transports Canada, qui a fait dans son exposé introductif, un bref rappel de la question de la résistance à l'écrasement des petits avions et évoqué le rôle de Transports Canada dans l'évolution de la R&D dans ce domaine. Il a également rappelé le premier objectif du colloque, à savoir poser le premier jalon d'un programme de R&D coopératif associant le gouvernement canadien et les milieux industriels et universitaires du Canada, d'une part, et, d'autre part, le Canada aux États-Unis.

M. Bill McLaren du CDT de Montréal a présenté les quatre conférenciers de la matinée représentant des organismes canadien et américains et dont les communications sont résumées dans les pages suivantes. Ces organismes sont: le Bureau canadien de la sécurité aérienne (BCSA), le National Transportation Safety Board (NTSB) et la Federal Aviation Administration (FAA), ces deux derniers des États-Unis. Deux films ont également été projetés, fournis par la National Aeronautics and Space Administration des États-Unis et présentés par le Dr. Chandler du Civil Aviation Medical Institute (CAMI), organisme relevant de la FAA.

En après-midi, M. James Torck a animé un débat libre d'experts représentant le BCSA, la FAA, la de Havilland du Canada, l'Université de Toronto, Transports Canada et le Conseil national de recherches (établissement aéronautique national). Après un exposé introductif fait par chacun des six participants, les débats libres ont commencé, les représentants de Transports Canada et du Conseil national de recherches ayant fait pour leur part le point sur l'orientation donnée à la recherche et au développement au Canada.

"Accidentologie des petits avions au Canada", William Tucker, directeur, Programmes de sécurité, Bureau canadien de la sécurité aérienne (BCSA).

Une diminution du nombre d'accidents aux 100 000 heures de vol a été constatée, ce nombre passant de 19 en 1976 à 15 en 1986. Durant cette même période, le nombre d'accidents avec tués est tombé de 2,4 aux 100 000 heures à 1,5. Par contre, exprimée en pourcentage du nombre total d'accidents, la situation est demeurée essentiellement inchangée. Cela signifie que les chances de survie après un écrasement ne se sont pas réellement améliorées.

La gravité des dommages corporels et le nombre de tués sont généralement reliés à la gravité de l'accident, décrite en termes de degré d'endommagement et d'angle au moment de l'impact. Cependant, l'analyse des accidents indique qu'il y a de nombreuses exceptions à cette règle. En effet, il y a eu des tués à la suite d'accidents sans grande gravité tandis que dans certains accidents graves, aucun tué n'a eu à être déploré. De nombreux autres cas ont été constatés où la mort est survenue non pas à l'impact initial, mais consécutivement à l'écrasement: impact secondaire, incendie, etc. Les chances de survie sont d'autant plus fortes que l'impact est moins brutal, comme c'est le cas lors d'une collision avec des arbres ou un plan d'eau, par opposition à une collision contre un flanc de montagne.

Le harnais de sécurité joue un rôle sécuritaire important. La proportion des petits avions équipés de harnais est passée de 32 à 50 p. 100 au cours de la décennie, mais entre 75 et 80 p. 100 seulement des occupants les utilisent, lorsqu'il y en a. Les analyses montrent que le nombre de tués est de 60 p. 100 plus élevé lorsqu'il n'y a pas de harnais et que ceux-ci auraient pu sauver la vie à 28 p. 100 de ce nombre, et atténuer la gravité des dommages corporels dans 90 p. 100 des cas. Le BCSA a demandé à Transports Canada d'exiger que tous les avions commerciaux soient équipés de harnais et d'insister pour qu'il en soit de même pour les avions privés.

Il est d'autres points qui, tout en étant conformes aux critères de navigabilité, ne répondent pas aux exigences d'aptitude à la survie. Exemples, la rupture de l'hélice au moment de l'impact et le danger que cela peut représenter et la facilité avec laquelle la porte de l'avion écrasé peut être déverrouillée pour permettre l'évacuation des occupants.

L'auteur termine en disant que les chances de survie pourront être grandement améliorées rien qu'en focalisant la recherche sur les lacunes les plus évidentes.

"Conclusions des études sur la résistance à l'écrasement en aviation générale, sommaire du National Transportation Safety Board, Gerrit Walhout, enquêteur principal (NTSB).

La résistance à l'écrasement est l'aptitude d'un avion à protéger ses occupants contre les dommages corporels consécutifs à une perte des qualités aéronautiques due à un facteur particulier ou à une association de facteurs, mécaniques, humains ou météorologiques. Les trois grands facteurs de survie sont: la résistance de la cellule, les dispositifs d'immobilisation des occupants et l'emploi de matériaux amortissants. Un quatrième facteur est celui de l'incendie post-accident.

L'auteur fait un rappel de la recherche dans le domaine de la résistance à l'écrasement depuis les années 1940 jusqu'en 1970, année où le Civil Aeronautics Board des États-Unis a formulé des recommandations qu'il a soumises à la FAA. Celles-ci ont concerné les harnais de sécurité, l'emploi de matériaux amortissants dans la cellule, les essais dynamiques, la résistance des sièges et la sécurité du circuit de carburant. Rien ou presque n'a été fait depuis pour des raisons institutionnelles.

En 1980, le NTSB a lancé un programme de recherche pluriannuel sur l'amélioration des chances de survie par la valorisation des normes afférentes. Une des approches suivies a été de soumettre un large échantillon d'accidents à une analyse statistique significative, une autre de procéder à une analyse en profondeur d'un échantillon restreint mais sélectif, le tout dans le but de cerner la marge de survie à un accident.

La recherche a montré que cette marge occupe l'intervalle compris entre un impact à zéro degré et à 75 noeuds et un impact à 90 degrés et à 45 noeuds. La limite supérieure de cette marge a été fixée comme suit dans le sens horizontal, de 30 à 35 g et de 60 à 70 pieds par seconde pour ce qui est de l'accélération et des variations de vitesse, respectivement; dans le sens vertical, de 25 à 30 g et de 50 à 60 pieds par seconde, respectivement.

Les deux analyses ont donné des résultats analogues, à savoir:

	Échantillon large (%)	**Analyse en profondeur (%)**
- tués que le port du harnais aurait pu sauver	75	65
- blessés graves que le port du harnais aurait pu mieux protéger	88	77
- blessés graves qu'un siège en matériaux amortissants aurait pu protéger davantage	34	24

On constate que les résultats les plus frappants sont liés au port du harnais. Quant aux sièges en matériaux amortissants, s'ils ne réduisent le nombre de tués que par 2 p. 100, ils réduisent le nombre de lésions permanentes de l'épine dorsale par 34 p. 100, qui est aussi fonction du poids de l'occupant.

Le groupe de travail sur la sécurité en aviation générale a formulé des recommandations de nature à améliorer les chances de survie sans contrepartie excessive sur les plans technique ou financier. Les analyses qu'en a faites le NTSB montrent que ces recommandations devraient être considérées comme des normes de conception minimales en matière de protection des occupants.

"Sièges et dispositifs d'immobilisation en aviation générale: critères de performances et essais dynamiques", Richard Chandler, superviseur, Protection and Survival Research Laboratory (FAA) Civil Aeromedical Institute.

Avec un effectif de 18 personnes, le laboratoire oeuvre dans les trois secteurs suivants:

1. mise au point d'installations d'essais dynamiques économiques;
2. programmes d'essais coopératifs avec d'autres organismes et le secteur privé;
3. mise au point de méthodes d'essai.

Pour les programmes coopératifs, il a fallu surmonter les réticences du secteur privé causées par les contentieux en cours, mais des programmes ont pu être lancés avec Beech, Piper, Cessna, et Boeing-Vertol. En 1984, le laboratoire a participé aux travaux de mise au point de modes opératoires qui ont mené aux recommandations du General Aviation Safety Panel (GASP).

Des essais dynamiques atteignant jusqu'à 30 g d'intensité ont été menés. Mais ce sont les impacts secondaires, à l'intérieur même de la cabine, par exemple, qui causent la plupart des dommages corporels. Un programme d'étude, lancé en 1982 avec la coopération de Cessna, a débouché sur un dispositif intégré d'immobilisation et d'ancrage de siège en matériaux amortissants pour le nouveau Caravan. Ce programme ainsi que deux autres, ont été à la base des travaux du GASP. Les résultats, obtenus en moins d'un an et auxquels a adhéré un groupe aux intérêts variés, couvrent principalement les secteurs suivants:

- essais dynamiques jusqu'à 26 g vers l'avant, y compris les forces de lacet, et jusqu'à 16 g verticalement;
- prise en compte des déformations du plancher dans le cadre du mode opératoire;
- critères de dommages corporels, y compris les commotions médullaire, thoracique et crânienne;
- spécification concernant les ceintures abdominales et les harnais;
- méthode d'essai dynamique de l'intégrité structurale du dispositif d'immobilisation, transposée aux essais statiques;
- mise en oeuvre au sol et en vol d'une masse de 215 lb (et non plus de 170 lb) représentant le poids d'un occupant.

Les résultats de ces travaux sur des dispositifs d'immobilisation améliorés sont maintenant diffusés sous forme de circulaires, de modes opératoires statiques et dynamiques tandis que la norme 8043 de la SAE a été adoptée à titre de TSO.

Mais de laborieuses recherches restent à faire dans les secteurs suivants:

- dispositif d'immobilisation économique pour les besoins du marché secondaire;
- essai non destructif des fixations correspondantes;
- techniques de contrôle, notamment des composants non métalliques, les sangles, par exemple;
- plateaux de siège de remplacement bon marché;
- méthode de contrôle d'enrouleurs automatiques autoverrouillants.

Un dernier secteur à approfondir est celui des sièges tournés vers l'allée, pour lesquels il est difficile de mettre au point un dispositif d'immobilisation efficace.

"Circuit de carburant en aviation générale: dynamique d'écrasement, Stephen Soltis, National Resource Specialist (FAA).

Une action lancée en 1982 par le GASP pour renforcer l'aptitude à la survie s'est concentrée sur les deux secteurs suivants: résistance du siège/protection de l'occupant et déversement de carburant/incendie postécrasement. Étant donné qu'il fallait faire appel à des technologies différentes, le groupe GASP-2 a été mis sur pied en 1984 pour mieux approfondir le second sujet. Ainsi, il a répertorié la fréquence des déversements et des incendies postécrasement; l'incidence des dommages corporels, y compris les cas de décès; les sources de déversement et les sources possibles d'allumage.

Sur 121 cas d'accidents où il y a eu des survivants, 96 ont donné lieu à un déversement (79 p. 100), la rupture des réservoirs étant à incriminer dans 78 des cas. Il y a eu aussi cinq cas d'incendie postécrasement avec tués. Une étude a été lancée sur les réservoirs de carburant souples anticollision. Le premier aspect abordé a été celui de la perte volumétrique qu'ils occasionnent. Cette perte a été chiffrée entre 8 et 14 p. 100, selon l'épaisseur de paroi du réservoir, à laquelle s'ajoutent de 6 à 8 p. 100 dus au chemisage des réservoirs placés dans les ailes, calcul basé sur un profil d'aile en aviation générale d'une épaisseur type de 16 p. 100. Mais lorsque cette épaisseur est de 12 à 13 p. 100, comme dans le cas de certaines ailes fines, la perte volumétrique peut se situer entre 20 et 45 p. 100 car, alors, la partie réservoir occupe presque tout le volume disponible. Il y a en outre un surcroît de poids qui peut être de 1 à 3 p. 100 du poids brut de l'appareil. La perte d'autonomie qui en résulte peut se situer entre 8 et 14 p. 100.

Une solution plus judicieuse serait de ne placer des réservoirs souples que dans les endroits accessibles, à proximité de sources d'allumage. Les avions de référence utilisés pour les besoins de la recherche ont été ceux dont l'aile d'épaisseur standard est équipée de réservoirs souples ou rigides. L'augmentation du nombre des avions à ailes-réservoirs pourrait modifier l'incidence du déversement et des sources d'allumage mise en évidence par les travaux du groupe GASP-2.

En 1987, ce groupe a formulé des recommandations à propos de tous les avions de la catégorie aviation générale transportant moins de 10 passagers; elles concernaient les fuites aux jonctions des canalisations avec l'équipement alimenté (huit onces maximum) réservoirs à l'épreuve des collisions, y compris des moyens de réduire les fuites et des dispositifs autres que les réservoirs souples; et une circulaire d'information fondée sur la spécification militaire correspondante dûment modifiée.

SMALL AIRPLANE CRASHWORTHINESS
RESEARCH AND DEVELOPMENT
SEMINAR

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INTRODUCTION

WILLIAM S.C. MCLAREN (Chief, Current Technology Division, Transportation Development Centre Transport Canada): Good morning. Welcome to the Small Airplane CrashWorthiness Research and Development Seminar.

Before we start, I have three announcements to make. The first is that smoking is not allowed in this room, though it is allowed in the room just around the corner as you go out to your left.

Next, I have been asked to announce that, with regard to the report on the small aircraft crashworthiness study recently completed for Transport Canada by Sypher:Mueller, we were unable to supply the demand. The report is to be reprinted, and those who have not already received a copy will get one.

Thirdly, I would like to remind you that these proceedings are being reported, and you will also receive a copy which will be sent to you after the seminar. So when you speak, will you please identify yourself and speak through the microphones.

It is now my pleasure and privilege to introduce to you Claude LaFrance, Assistant Deputy Minister, Aviation for Transport Canada, who is to give the opening remarks to this seminar.

OPENING REMARKS

MR. CLAUDE LAFRANCE (Assistant Deputy Minister, Aviation, Transport Canada): Thank you.

Good morning, ladies and gentleman.

On behalf of Transport Canada, it is both my pleasure and privilege to welcome you to this very important seminar on small airplane crashworthiness.

We have, all of us in the business, recognized for some time that a great deal can be done to reduce the incidence of both death and serious injuries of passengers and crews in the small airplane accidents, and that this can be done through improved crashworthiness design and regulation.

We know, of course, that a great amount of research and development in this area has already been done, and, as we will certainly hear during the day, more work still needs to be done.

Now, the R & D is only a start, and after that we must then implement the required measures in new or improved crashworthiness standards - this to further improve as a record of survivability in that kind of accident, as well as reducing injuries, of course.

Now since many of these changes will likely involve some regulatory activity with retroactive effect, the costs and benefits of these proposals must be carefully evaluated.

We are grateful to the Transportation Development Centre of Transport Canada for funding this seminar today. This is a positive step in the process of defining the road ahead, and as part of this, the Transport Development Centre had previously funded the study by Sypher:Mueller, which provided recommendations that led to this seminar.

We are delighted and grateful to see the number of experts from the United States here today. Some will be addressing us in the first part of the seminar, and others will participate in the discussions after the luncheon. We are, of course, sharing a continent and fine traditions, and also similar types of airplane, similar weather and navigation systems. I think we can all benefit from our shared experience.

I am also pleased to see the excellent participation by the Canadian Aviation Safety Board today, as well as from a number of representatives from the Aviation Industry, research organizations, including the distinguished representatives from the National Research Council, as well as pilots and owners.

Finally, as should be obvious from looking around the room, my own department is well represented. For us, at Transport Canada, the object is primarily to listen and to learn. In the following days we will take what we have learnt to establish where we can make a Canadian contribution to the remaining R & D problems, and how we could consider of possible changes to our regulations - all this with a view to enhance the crashworthiness characteristics of small aircraft.

Now, you have in front of you a well-thought-out and very complete agenda.

Once again, my sincere welcome to all of you at this very much needed seminar. I wish you a fruitful session; and I now turn over the microphone to Mr. Torck, Transport Canada's Director of Airworthiness, for his opening remarks.

Thank you.

MR. TORCK: Thank you very much, Mr. LaFrance.

Good morning, ladies and gentlemen. I would like, if I may, to add our own welcome from the Airworthiness Branch.

My remarks are perhaps a little bit more specific, and they begin with a reference to my predecessor. Some two years ago Dr. Gerry Marsters, who held this position at that time, became concerned about small aircraft crashworthiness. His specific concern related to the four following issues: the numbers of deaths and serious injuries that possibly could have been prevented by improved crashworthiness provisions in place for these aircrafts; the apparent lack of a mechanism to coordinate R & D between Canada and the United States; the lack of regular, identified funding for Canadian crashworthiness research and development; and, finally, the lack of a coordinated Canadian effort to further research and development in this particular area.

As a result of these concerns, Transport Canada and the Transport Development Centre jointly funded the Sypher:Mueller two volume study, of which most of you have copies now, and of which additional copies will be made available later.

"Overview of North American Research and Development in Small Aircraft Crashworthiness" reviewed and analyzed past accident investigations, regulatory developments in crashworthiness research activities for small aircraft in Canada and the United States. From the analysis and the concurrent extensive interviews with the acknowledged experts in the field, six gaps or areas for further research and development, where this would be beneficial, were in fact identified. Two of these, which, in the view of the authors, would contribute most to the enhancement of the safety of small aircraft, and which, additionally, would be seen to comprise a meaningful Canadian contribution to joint aeronautical research and development between the United States and Canada, were finally identified and recommended.

Additionally, two actions were recommended. The first action, which also constitutes the objective of this seminar today, is to determine what the future focus of Canadian research and development activity in small aircraft crashworthiness really should be.

Once that direction is clear, it is anticipated that we would, as indicated by Mr. LaFrance, undertake the second task, that is, to move forward and develop a co-ordinated R & D program between government, industry, and university, all of whom are represented here today, which would not only contribute to enhanced safety in this area, but, we believe, would also lead to the improvement of the joint R & D effort between Canada and the United States.

Resources, as everyone knows, are limited. It is our hope that your participation here today will ultimately enable us to better direct our efforts to and in selected areas which will ultimately make for improvements in air safety for the benefit of the small aircraft operation.

We look forward, of course, to hearing from our speakers and look forward to your participation later in the panel discussions with a view to assisting us in achieving that, so far, elusive goal.

At this stage, I will turn over the floor to Mr. Bill McLaren, Chief of Current Technology, Transportation Development Centre, located in Montreal, whose task it is to chair this morning's session and, of course, to introduce our speakers.

A REVIEW OF NORTH AMERICAN RESEARCH AND DEVELOPMENT IN SMALL AIRPLANE CRASHWORTHINESS

MR. WILLIAM McLAREN (Chief, Current Technology, Transportation Development Centre): Thank you very much.

Our first speaker this morning will be William Tucker. William Tucker was born in St. John's, Newfoundland, and attended Prince of Wales College and Memorial University. He received his engineering degree from Nova Scotia Technical College in 1966.

He served as a pilot with the Canadian Armed Forces until the fall of 1970, when he returned to University.

He graduated from the University of Western Ontario with a Masters Degree in Business Administration.

He then joined Transport Canada and held successively more responsible positions - in airport planning, in civil aeronautics planning and research and, for nine years, in the area of aviation statistics and forecasts.

Then in 1983 he joined the Aviation Safety Bureau. In 1984, with the termination of the Bureau and the establishment of the CASB, he became the Board's Director of Safety Programs.

Mr. Tucker's responsibility in his present position is for safety deficiency analysis and recommendations, public affairs, policy and planning and EDP Systems.

The title of Mr. Tucker's presentation this morning is "Small Airplane Accident History".

Mr. Tucker?

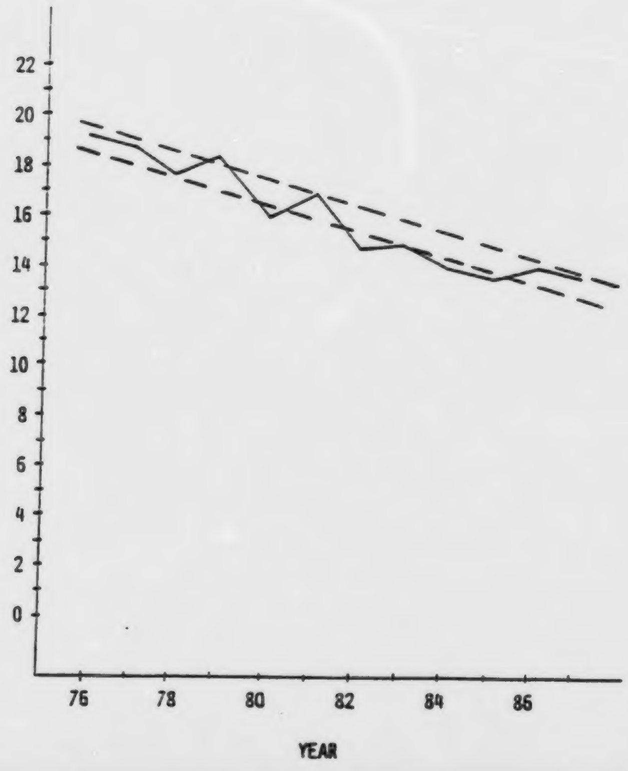
Small Airplane Accident History in Canada

MR. WILLIAM TUCKER (Director, Safety Programs, Canadian Aviation Safety Board): I have just brought a few visual aids, and since this is a workshop, as opposed to a more formal conference, I felt it best to keep the presentation equally informal and do some scene setting, and hopefully generate some information upon which we can base our subsequent discussions as to where we go.

As to the first slide we have got here, we are talking about crashworthiness, and to put it in its simplest form, what we are trying to say is: if we are going to have accidents, let us see how we are going to get out of them with damage, injuries minimized.

ACCIDENT RATE

(ACCIDENTS PER 100.000 HOURS FLOWN)



We have in Canada roughly 500 accidents a year. It was fairly steady at 700 through most of the seventies and early eighties, and fell to about 450 or so; and then, as the recession wore off and traffic started to grow again, the number of accidents increased to just under 500.

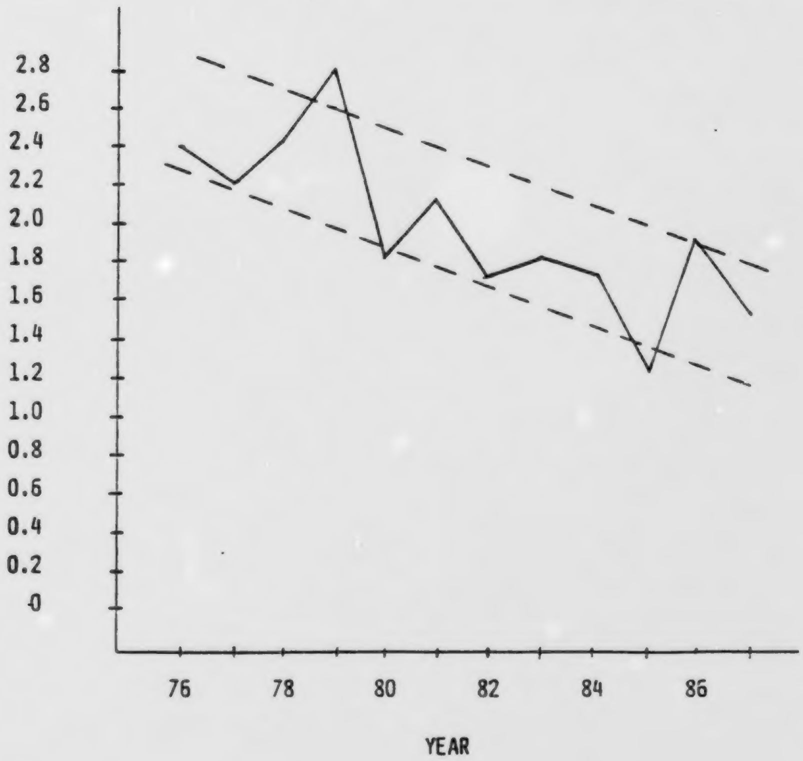
However, when you look at the accident rates you can see that there is a very consistent downturn through 1987 as well.

But what is more important, though, for what we are talking about in this workshop, is fatal accidents.

The fatal accident rate is certainly more erratic because there are smaller numbers: but, again, you can see a downturn - less regular, but clearly a downturn in terms of fatal accidents per 100,000 hours flown.

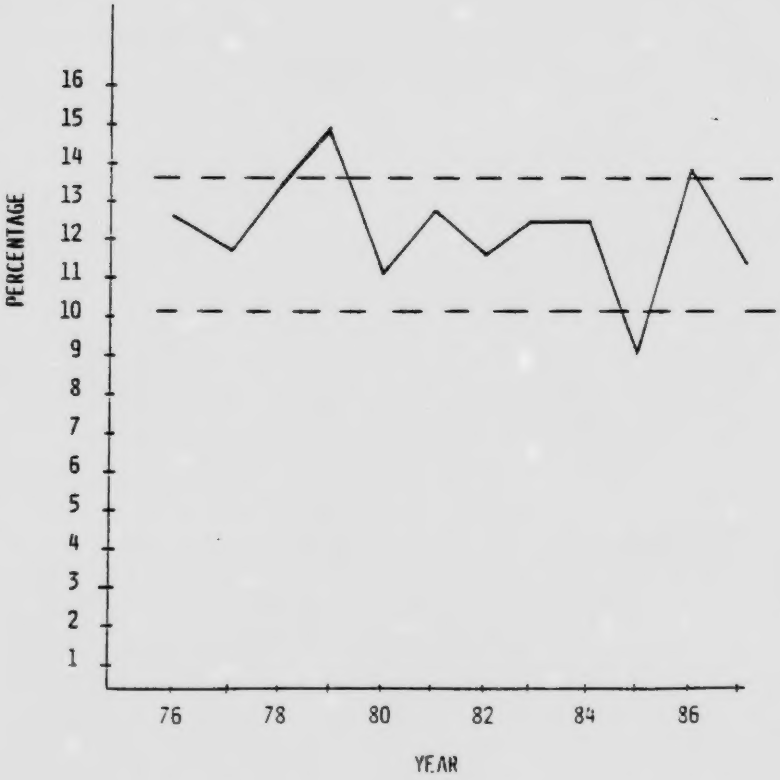
FATAL ACCIDENT RATE

(FATAL ACCIDENTS PER 100.000 HOURS FLOWN)



And then, the third overhead is showing fatal accidents as a percentage of total accidents. Here, you can see a rather interesting pattern. While it is fluctuating, and, I guess, on a pure regression you get a slight downturn, essentially it is constant.

ACCIDENTS WITH FATALITIES AS A PERCENTAGE OF TOTAL ACCIDENTS



Now, if you combine with that the fact that the average number of people killed per fatal accident is constant, and the average number of occupants per aircraft is also a constant, you can see that the survivability has not really improved at all over that time frame and that is really part of the focus of what we are trying to do here: Can we reduce accidents - the rate, and get the benefits? But, even if we can't reduce the accidents, maybe there are further benefits to be gained in crashworthiness.

Now, just to set the scene in what is involved in crashworthiness, I did some computer runs to give you an idea of what we have got in our data base.

It is rather interesting. We don't go to any great lengths in terms of crashworthiness detail per se in accident investigation. We have an 18 page data sheet and a four page supplementary on crashworthiness, which people are aware of if they have read the Sypher:Mueller report. But, still, within the general data we pick up a fair bit of information.

Now, for example, one of the runs there is looking at the fatalities and serious and minor and nil injury results, according to the degree of aircraft damage, ranging from no damage to minor, moderate, severe and extreme. Of course, what you will find is that the percentage of fatalities is higher in the case of extreme damage and much lower in the case of minor or nil - very logical.

But the interesting thing is, if you look at some of the accidents with extreme damage, you will get out sometimes without any injuries, or with only minor injuries. Similarly there are cases where the aircraft has minimal damage and people are dying. I think that is probably an area where we can gain a lot of value; we talk about the 80-20 Rule: We can probably get 80% of the result from 20% of the effort in this area.

Again, another run is that we looked at the angle of impact.

Now part of what we have in our system is with the terrain or object when the aircraft strikes it. I did research on both - aircraft, collision with ground terrain, trees, whatever, and occurrences that were not identified as fatal occurrences; and for those where there was a collision, we looked at the angle of impact, and it spread off or ranged from zero to 15 degrees and 15 to 30, and 30 to 45, and so on. I will not bore you with all of the odd numbers, but just to tell you the trend, very logically, that when the aircraft hits at low angles of impact, you have a higher percentage of survivability and low levels of increase; and at the other extreme, hundreds.

On the other hand, again, we have zones where there were a fair number of accidents in which the angle of impact was under 15 degrees and people are dying, and you also have accidents at the upper end, very steep angle of impact, and yet people survived. So that is an area again where we can consider why are people surviving in some of the serious accidents and they are dying in somewhat minor accidents.

Then we have another run, which is referred to in the study - this question of survivability; it is difficult, because it is certainly very judgmental. The tendency will be for an investigator looking at an accident where everybody is killed to say the accident was not survivable. There are guidelines, of course, to look at whether the cabin remained relatively intact; was it reasonable - what was the cause of death in a case where - and there was a case in Canada where a pilot survived the initial impact, but on the force, when the aircraft came to rest, with the deceleration forces, in the absence of upper body restraint systems, his head went forward into the altimeter, or some such instrument, right through his forehead and that was the cause of death; and I would suggest that therefore needs to be reinforced - if that happens, that is a totally wasteful situation and certainly, it leads to the loss of life, and it needs to be corrected.

In looking at the accidents where people survived what appeared to be a serious accident from the point of view of aircraft damage, and so on, I have not done any kind of systematic analysis, just a brief print, and I suspect that the best way to get results from this is for a fairly detailed analysis, through the accident files in total. I just looked - skimmed over.

But two or three things come out. First of all, aircraft could hit trees in many cases, so there is a gradual deceleration level on sudden impact than you encounter at slow speed - and helicopters, especially at low speed, aircraft or helicopters - over water. Again, the water is a little more forgiving than a cliff, or an abutment.

Now, we look at the nature of accidents - perhaps we can have that other slide. I just picked out this one. This is an accident which occurred in November, 1986. Shortly after takeoff, a Mooney M-20-C crashed in a marshland and was totally destroyed. The investigation revealed that the rear seat attachment was broken, and a passenger, who sustained fatal injuries, was sitting on the rear seat. You can see the wreckage inside there, and the state of the internal part - that part of the cabin. The failed seatbelt was forwarded to the CASB Engineering Branch, and they determined that the rear seatbelt attachment fitting had failed at the point marked there with the arrows. It failed to restrain the rear passenger from being knocked around in the aircraft as it crashed through the trees. There is an extremely good chance that person could have survived, even if they had an accident, if it had been held in place.

Again, this just shows the path of the accident, and the point where the aircraft came to rest.

There were no manufacturing or material deficiencies found contributing to the failure of the seat belt.

What I am trying to get at, for example, is this. A seatbelt is a fairly simple device. A shoulder harness is a fairly simply device, and we have reached the stage, painfully, I guess, over 20 years or so, where the use of seatbelts in cars have become common place. The use of seatbelts in aircraft is becoming more common place, but it is still not there.

The CASB has just completed a study on the influence of shoulder harnesses on aviation safety. We have brought about 25 to 50 copies for those who want it; it was just released two days ago, so if you do want a copy, see me - or Jim White has some copies as well.

So what we have found is that we went through our accident statistics for a ten year period, that the installation of shoulder harnesses in small aircraft is still fairly low. At the beginning of the study period it was around 32%, and in the later years up around 50%. We are still only running an average of 75% to 80% of the people who have the shoulder harnesses installed that use them.

And we have found from a study of the fatalities, that is the fatal accidents vs. the non-fatal accidents in cases where the shoulder harnesses were installed and used as compared with those cases where they were not installed or where they knew it was installed and yet they were not used: the fatality rate was about 60% higher in the latter case.

In effect, the study is saying that, in rough terms, we could potentially be saving 28% of the lives if shoulder harnesses were installed and used in the front seats; and there have been similar studies done in the United States that come to the same kind of conclusion.

Furthermore, the us study got further into the degree of injury, and found that 90% of the people injured in small aircraft accidents could have a reduction in the severity of their injuries - and that, of course, is another useful result; even if people get injured, it is certainly better for society if the injury is less.

Our Board has therefore just recommended to the Minister of Transport two things. The first one is that the Department of Transport require the installation of shoulder harnesses where practicable in the flight crew seats of all small commercial aircraft, regardless of their date of manufacture.

We have limited it to commercial aircraft for a number of reasons, the main one being that it is in the commercial area that government has, I guess, more of a mandate for involvement, and the board has decided to go with the carrot rather than the stick routine in the private category, and has recommended a broad commercial campaign to encourage the installation and use of shoulder harnesses in small aircraft.

We see that as being potentially of tremendous importance.

There are several other areas where the board has done studies and made recommendations - in fact, quite coincidentally, also this week, there was a study released on an accident by an Aerodale D-8-C; and in that accident, very early in the process, it was found that during the crash sequence a propellor came loose, and one of the blades became embedded in the cabin, and, fortunately, there was nobody sitting there, and nobody got hurt.

But as we looked into the situation behind it, we found that the degree of attention in the certification process to crashworthiness is very low. The attention is in airworthiness; and so the mechanism by which that prop was being retained was fine from an airworthiness point of view, but as the propellor starting striking, in this case I guess it was mud and snow combination, but it could be water, it could be tarmac, whatever - the forces on the blade as it stands, are quite different and the retention system is not built to protect it.

So we have encouraged through our recommendation - I guess about a year and a half or two years, co-operation between Transport Canada and the FAA to address that, and it is being looked into.

Now, survivability in the sense of post-crash fires tend to catch the news more in the large aircraft, but there are still situations in the small aircraft area which are very vivid - not as stark for the headlines, but the small numbers add up; and when you look at situations where occupants of aircraft are unable to get the seats - the doors open from their seats, rather complex mechanisms, some of these small aircraft 30 or 40 years ago, like the Beaver; it reinforced the need for a recommendation on the shoulder harnesses front and from the CASB viewpoint, because, in effect, the pilot of a small aircraft serves the same role as the flight attendant on a large aircraft, and that person becomes the only person in authority that can help the other occupants; and we have had several cases where a pilot has escaped from an aircraft and had, in some cases under water, to get a door open from the outside to get the passengers out from the back.

I think, as I say, if we poke around on the most glaring examples, there is a hell of a lot to be done to improve survivability and to improve the number of injuries.

I will leave you with those thoughts. Thank you.

MR. McLAREN: Thank you, Bill.

The next speaker this morning will be Gerry Walhout of the National Transportation Safety Board. Mr. Walhout was born in the Netherlands and in the early part of his career served with the Royal Netherlands Airforce.

After moving to the United States, he joined, first, the Aviation Safety Engineering and Research Division of the Flight Safety Foundation of Phoenix, Arizona, and he worked there as a design engineer for a period from 1959 to 1966.

He then, in 1966, joined the National Transportation Board, and has held several positions with the Board since then.

At present, he is senior investigator assigned to human performance division of the NTSB, responsible for the investigation of psycho-physiological aspects of accident causation. He also has duties connected with education and liaison.

He will be speaking to us this morning about the findings of the General Aviation Crashworthiness Project, the summary report of the NTSB.

Mr. Walhout.

General Aviation Crashworthiness Project Findings: Summary Report of National Transportation Safety Board

MR. GERRIT WALHOUT (National Transportation Safety Board):

Crashworthiness - The ability of the airplane to protect its occupants from injury after its airworthiness has been compromised through one or a combination of mechanical, environmental, or human factors.

This is one of a number of definitions on this subject that is defined by three issues:

1. Airframe strength
2. Occupant tie-down capability
3. Energy Management

A fourth issue, which is peripherally related is post-crash survival, that is, the problem of fire after impact.

To put the subject of crashworthiness in perspective, let me provide a very brief background of the Safety Board's interest in this area.

The word - crashworthiness -probably was coined by Hugh Dehaven, who in the 1940's, after his own survival and non-survival dichotomy he observed among military, and after the war, civilian airplane pilots and passengers.

By way of Cornell University, the Flight Safety Foundation and a private research organization, this research project ended up in Phoenix, Arizona, where it performed contract research in crashworthiness for the U.S. army. From that research came the now well-known - crash survival design guide - published by the U.S. Army in 1967.

In 1959, the Bureau of Safety of the Civil Aeronautics Board, the forerunner of the safety board, organized a human factors branch, specifically to investigate the survival factors of U.S. civil aviation accidents. From its accident investigation experience in those ten years, the Safety Board in 1970 recommended to the FAA:

1. That shoulder harness be required on all general aviation airplanes.
2. That energy absorbing materials be required on interior structures of GA airplane cabins
3. That dynamic testing be substituted for the present static test requirements for airplane seats.
4. That the emergency landing inertia forces that govern the strength of cabin furnishings, including seats, be raised to a suggested 20 to 25 G in the longitudinal direction and proportionally in the other axes.
5. That fuel tanks and fuel system be designed to minimize the spillage of fuel in moderate to severe crashes.

These five 1970 recommendations formed the basis for the Safety Board's subsequent activities in airplane crashworthiness after our dialogue with the FAA on the implementations of these 1970 recommendations for increased crashworthiness requirements for general aviation airplanes became unproductive, (and I hasten to add, because of institutional peculiarities rather than problems with individual FAA experts) the Safety Board in 1986, decided to provide its own research, (an activity for which it is not particularly well suited nor funded) and provide the data to validate the board's past findings and to support its crashworthiness recommendations.

Thus, in 1980, the safety board began to plan for a multi-year with the objective of developing and disseminating to the FAA and the general aviation industry an envelope of likely peak accelerative forces in survivable accidents and their effect on the occupants as well as the airplane structure in order to upgrade occupant protection design standards.

A study plan was developed which attacked the problem on two fronts:

1. One method was to perform a qualitative, and statistically significant, analysis of a large number of accidents to determine the impact of severity of typical survivable accidents and to design a survivability envelope for typical general aviation airplanes. Also, this analysis was to make a determination about the potential survival effects of shoulder harnesses and energy absorbing seats. This activity is described in the Safety Board's safety report NTSB/SR-85/01.[1]
2. The other program was to perform an in-depth analysis of a small number of selected accidents to define more precisely the limits of likely peak acceleration loads and velocity changes in typical survivable accidents. This activity is described in the Safety Board's safety report NTSB/SR-85/02.[2]

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[1] Safety Report: "General Aviation Crashworthiness Project: Phase two - impact severity and potential injury reduction in general aviation accidents". NTSB/SR-85/01; National Transportation Safety Board, Washington, D.C. 20594; March 15, 1985

[2] Safety Report: "General Aviation Crashworthiness Project: Phase III - Acceleration loads and velocity changes of survivable general aviation accidents". NTSB/SR-85/02; National Transportation Safety Board, Washington, D.C. 20594; September 4, 1985.

In order to perform these study objectives, a simple kinematic analysis was devised which only required data that could be readily collected at the crash scene using standard investigative techniques. In addition to data involving occupant injuries, seat retention shoulder harness and seatbelt performance, precise impact information regarding ground scars and fuselage deformation was obtained. Simple orthographic drawings were then used to reconstruct the airplane's attitude at impact.

One technique to establish impact attitude was through the use of the crush line, formed as a result of airframe deformation against a flat surface at impact which leaves a distinct "stamped" area on the fuselage. The stamped area could then be reproduced on an orthographic drawing and oriented to the earth axes.

Once the airplane's attitude was determined, a crash pulse could be developed which, when integrated, generated velocity change and stopping distance. The details of this technique are described in the Board's safety report NTSB/SR-83/01.[3] This report also contains verification details of the accuracy of this analytic technique with the test data from NASA full scale small airplane crash test program that was concluded in 1982.

With respect to the results of the Safety Board's Phase II study, regarding impact severity and injury prevention, the Safety Board's 1982 data base was used to select accidents in which at least one occupant was fatally or seriously injured. Certain airplanes were excluded, such as aerial application airplanes, home-builts, and other airplanes of "fabric and tube" construction. The selection also was limited to those makes and models which were expected to continue to be in production and thus, the most likely candidates for improved crashworthiness designs. The foregoing selection process resulted in 535 accidents involving 1268 occupants, of which 301 accidents involved at least one fatality. There were 859 fatalities in the 391 accidents, 74 occupants were seriously injured and 19 occupants survived with minor or no injuries. In 85% of the 391 accidents, all occupants were fatally injured. In the remaining 144 accidents, 228 occupants were seriously injured and 87 occupants received minor injuries. One occupant's injuries could not be determined.

PHASE II STUDY

DATA BASE

535 TOTAL ACCIDENTS	1268 TOTAL OCCUPANTS
391 FATAL ACCIDENTS	859 FATALITIES
	74 SERIOUS INJURIES
	19 MINOR INJURIES
144 NON-FATAL ACCIDENTS	228 SERIOUS INJURIES
	87 MINOR INJURIES
	1 UNKNOWN

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[3] Safety Report: "General Aviation Crashworthiness Project, Phase one". NTSB/SR-83/01; National Transportation Safety Board, Washington, D.C. 20594; June 27, 1983.

CONCLUSIONS

PHASE II STUDY

1. Shoulder harness use is the most effective method of reducing fatal and serious injuries in general aviation airplane accidents.

2. New crashworthy airframe design is the improvement which will most significantly expand the survivable envelope to higher impact speeds.

3. Impact severity, as defined by impact speed and impact angle, is a principal determinant of a survivable accident.

4. The accidents reviewed in this study generally were survivable within the envelope bounded by a line through an impact speed of 45 knots at an impact angle of 90 degrees, 60 knots at 45 degrees, and 75 knots at zero degrees.

5. A potential 20-percent reduction in fatalities could be realized if all occupants of general aviation airplanes were to wear shoulder harnesses.

6. Potentially, 88 percent of seriously injured occupants could be expected to incur significantly reduced injuries if shoulder harnesses were used.

7. A potential 2-percent reduction in fatalities could be realized with the installation of energy-absorbing seats.

8. Potentially, 34 percent of seriously injured occupants could be expected to have significantly reduced injuries if energy-absorbing seats were available.

9. Where shoulder harness availability and use could be determined, only 16 percent of the occupants were wearing a shoulder harness at the time of the crash. Shoulder harnesses were available to 40 percent of the occupants and, when available, were worn 40 percent of the time.

10. Twenty-seven percent of all seats in survivable accidents underwent some type of failure.

The analysis of this study group first concerned itself with impact severity of each accident in terms of impact angles and impact speed. Each accident was evaluated by an experienced analyst with respect to survivability. Impact angle and impact speed were concurred in as provided by the field investigator or adjusted as necessary. Each accident was then represented on a polar plot (Figure 1) with respect to its survivability determination. Next, each occupant similarly was plotted on a polar plot with respect to the survivability or non-survivability of the accident (Figures 2 and 3). These two figures were compared to establish whether the difference between survivable accidents and non-survivable accidents was one of the impact severity. Any differences that could be demonstrated would define the limits of the survivable envelope. The plots were overlayed and in another comparison the plots were redrawn as rectangular plots so that DOT density of the various sectors could be compared.

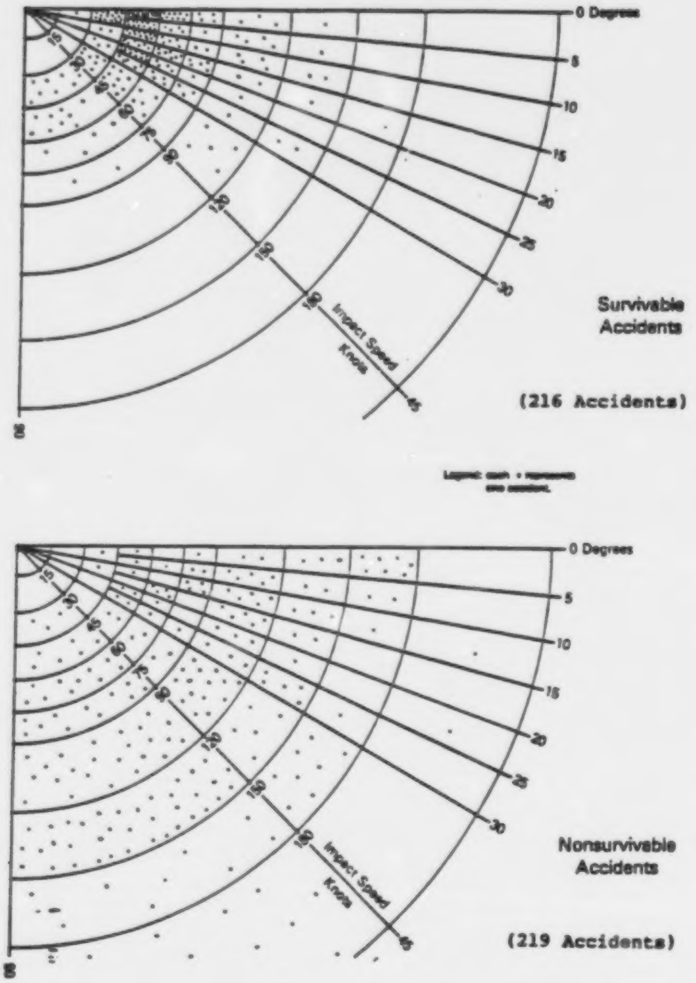
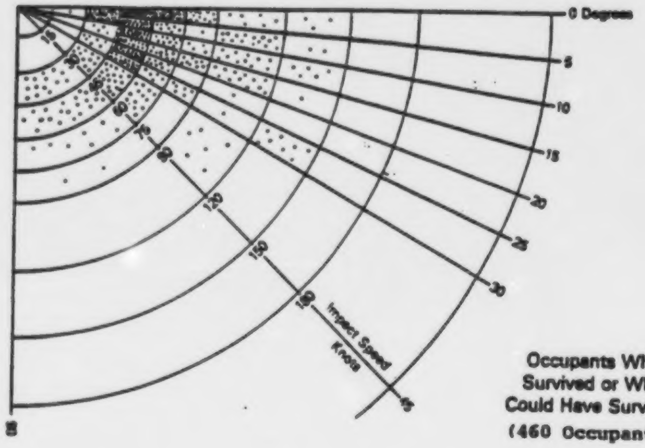
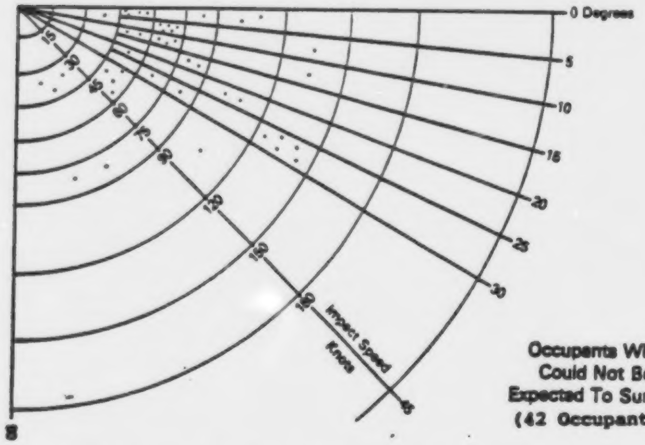


Figure 1. Impact Angles and Impact Speeds: Survivable versus Nonsurvivable Accidents

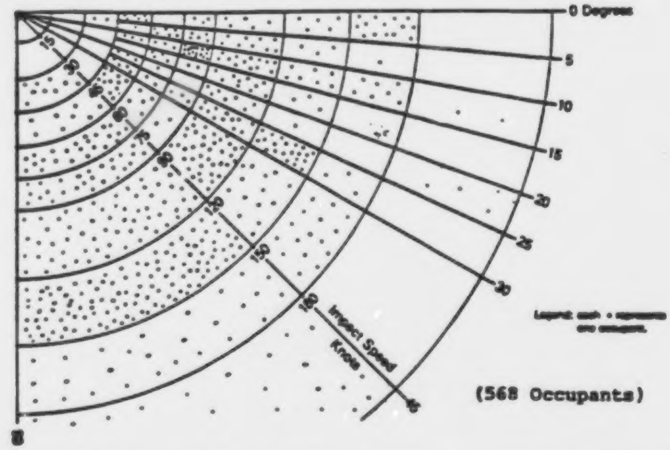


Occupants Who
Survived or Who
Could Have Survived
(460 Occupants)



Occupants Who
Could Not Be
Expected To Survive
(42 Occupants)

Figure 2. Impact Angles and Impact Speeds in Survivable Accidents Occupants Who Survived or Could have Survived versus Occupants whose Survival was not Expected



(568 Occupants)

Figure 3. Impact Angles and Impact Speeds: Occupants in Nonsurvivable Accidents

These comparisons produced a visible difference between the groups which is shown as a boundary line (Figure 4) extending from zero degrees at 75 knots, to 45 degrees at 60 knots, to 90 degrees at 45 knots.

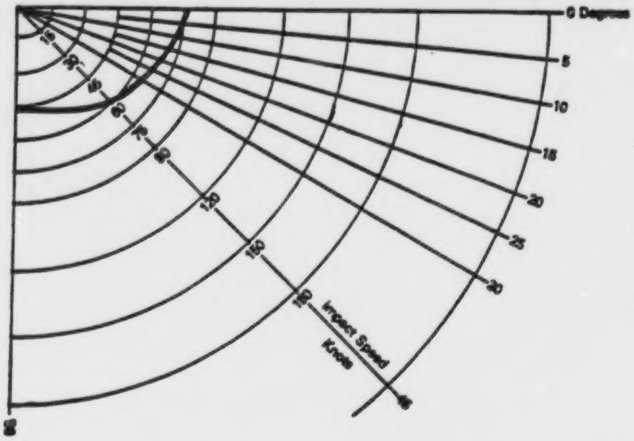


Figure 4. Survivable Envelope for General Aviation Accidents

Another important part of this study was the assessment of benefits to be derived from the use of shoulder harnesses and energy absorbing seats.

First, there were five survivable accidents in this data set in which shoulder harness were worn by only one of two front seat occupants. (Table 1) Impact angles ranged from near zero to 30 degrees at speeds from 30 to 75 knots. In each of these five accidents, the occupant with the shoulder harness had fewer and less severe injuries than the occupant without the shoulder harness. As expected, the differences in injuries in these cases were related to head and upper torso injuries.

Table 1. Side-By-Side Injury Comparison

	Injury level		Impact severity	
Example	With shoulder harness	Without shoulder harness	Impact speed (knots)	Impact angle (degrees)
1	Serious	Serious	45-60	5-10
2	Minor	Serious	60-75	0-5
3	Minor	Serious	45-60	0-5
4	Minor	Serious	30-45	25-30
5	Serious	Fatal	45-60	0-5

In each of these accidents, the occupant who wore a shoulder harness had fewer and less severe injuries than the occupant who did not. For example, in one accident each of two occupants sustained serious injuries, but the pilot, wearing a shoulder harness, sustained a broken leg and a slight concussion while the passenger without a shoulder harness sustained severe head injuries. The differences in the injuries in these comparisons were related to head and upper body injuries. Those persons who wore shoulder harnesses had markedly fewer head injuries. As would be expected, shoulder harnesses did not prevent injuries to the lower torso or to the extremities.

With respect to the benefits to be derived from a shoulder harness, two important elements must be satisfied. One, the shoulder harness must be available. Only 40% of all occupants had shoulder harnesses available. The second element is one of use. The shoulder harness cannot protect the occupant if it is not worn. Out of 425 cases in which shoulder harness were available, use could be determined in 100 cases, non-use in 153 cases, and unknown use in 172 cases. (Figure 7)

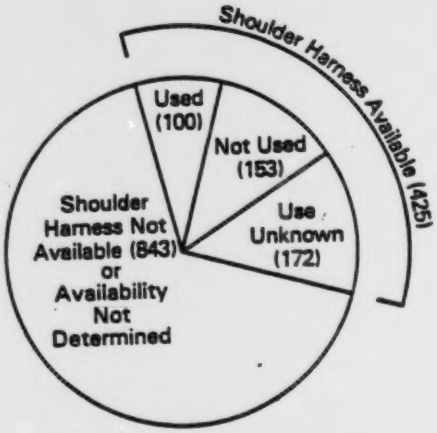


Figure 7. Shoulder Harness Availability and Use

Each of the 1268 occupants was evaluated separately with respect to specific injuries and an analysis was made to what extent these injuries could have been prevented or lessened through shoulder harness use (Figure 8 and table 2). It was estimated that at least 13 percent of the fatalities would have survived with serious injuries and that an additional seven percent would have received only minor or no injuries. The expected benefits are even more pronounced for those who were injured seriously. Fully 88 percent would have received less severe head and upper torso injuries or no injuries at all, had shoulder harnesses been worn. The benefit of shoulder harnesses becomes even more graphic if only survivable accidents are considered. When the occupants of the non-survivable accidents are removed from this data set, shoulder harnesses could have prevented 75 percent of the fatalities and 79 percent of the serious injuries. (Table 3)

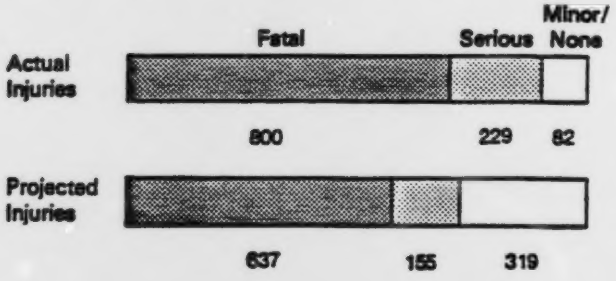


Figure 8. **Distribution of Occupant Injuries as Actually Occurring and as Expected with Full Shoulder Harness Use**

Table 2. Injury Distribution as Actually Occurring and as Predicted Given Full Shoulder Harness Use

Occupant injury level	Original injury distribution	Predicted injuries with shoulder harnesses	Percentage change
Fatal	800	637	-20
Serious	229	155	-32 (-41)
Minor/none	82	319	N.A.
	1,111	1,111	

Table 3. Occupants in Survivable Accidents: Potential Benefits of Shoulder Harness Use

Original injury distribution		Expected distribution with shoulder harnesses		Percentage
Fatal	216	Fatal	53	25
		Serious	106	49
		Minor/none	57	26
Serious	229	Serious	49 (21)	21
		Minor/none	180	79
Total of Fatal and Serious	445	Total who benefitted	343 (364) 1/	77 (82)

1/ The number 364 (82 percent) is compiled from the 106 occupants coded fatal to serious, the 57 occupants coded fatal to minor/none, the 180 occupants coded serious to minor/none, and the 21 occupants out of 49 who were coded serious to serious but would have had less serious injuries.

Estimates of energy-absorbing seats benefits are less dramatic. Such seats cannot be expected to prevent many fatalities since the preventable injury is a spinal injury. In survivable accidents, spinal fractures rarely result in a fatality. However, these injuries are severe, long lasting and costly. The Phase II data suggest that about 2 percent of the fatalities could have been prevented with the availability of an energy absorbing seat. The data also suggest that about 34 percent of the seriously injured occupant probably would have had less severe injuries to the back and neck had such seats been available.

An important consideration is that the occupant of a energy absorbing seat must remain upright and the seat must remain in place. This means the use of a shoulder harness, otherwise no benefit will be derived. It is of interest to note that nearly 27 percent of the seats in the survivable accident data set did not remain attached properly. Again, no benefit will accrue when the seat does not remain attached.

The most important conclusion that can be drawn from the Phase II study that shoulder harnesses are the most effective method of reducing fatal and serious injuries in general aviation airplane accidents.

Having established the impact parameters which define a survivable accident in terms of impact angle and speed, the next study phase attempted to establish the acceleration loads and velocity changes that define the limits of survivability in general aviation airplanes. Detailed on-scene investigations were conducted of 39 accidents which were selected for their severity as well as their potential survivability. Thus, the accident had to have a serious or fatal injury and also had to have at least one survivor. Fire accidents were rejected unless the fire was very minor. The final data set included 19 accidents with at least one fatality and 18 accidents without a fatality but with a number of serious injuries. In two accidents, the occupants had only minor injuries but the accidents were included because of the severity of the impact.

It was important to establish that the selected accidents were representative of the Phase II data with respect to their severity as well as their survivability so that the upper bounds of the survivable envelope could be better defined. To test that selection process, the 39 accidents were compared to the NASA crash test data as well as the 1982 NTSB data set (Figure 10). A second comparison looked at the potential reduction in injuries through shoulder harness use and energy absorbing seats. A third comparison compared airplane damage and severity of injuries with the Phase II data (Table 4). This established that the Phase III accident data set was representative and provided additional confidence about the calculated acceleration loads and velocity changes.

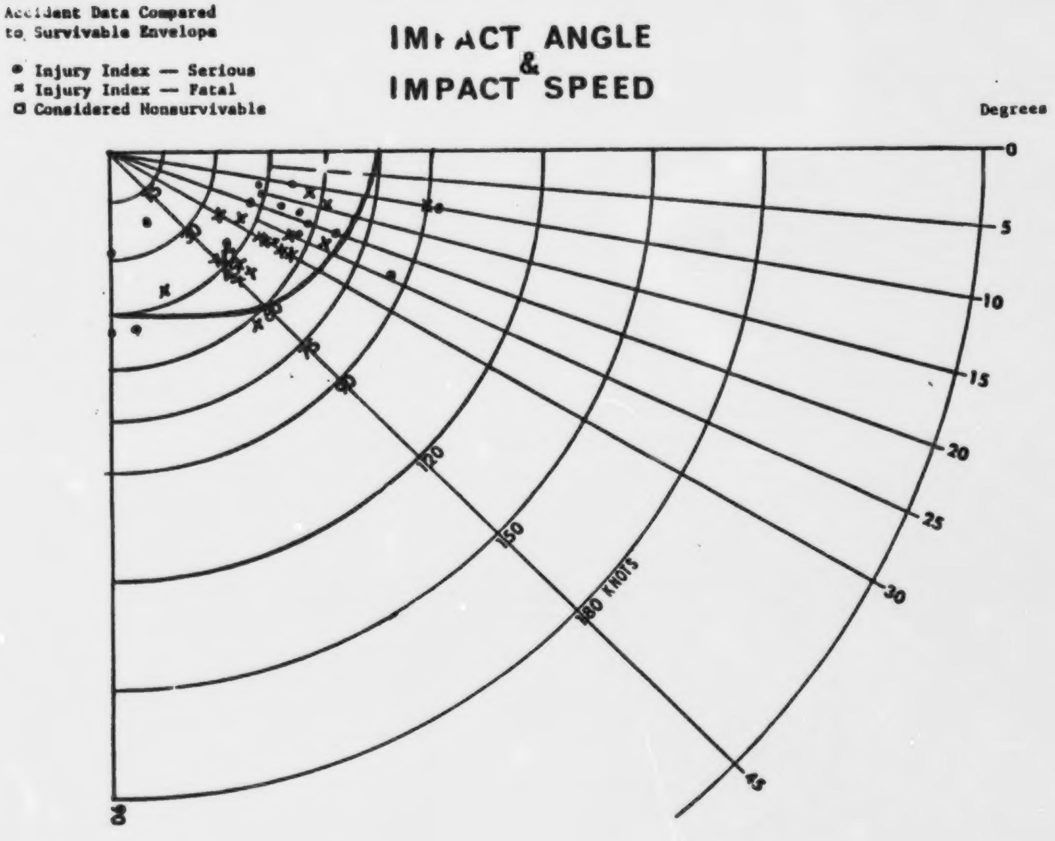


Figure 10. Impact Angle and Impact Speed of the Accident Cases Compared to the Survivable Envelope

Table 4. Comparison of Data from the Phase Two Study and the Phase Three Study

	Phase Two	Phase Three
Accidents	535	39
Occupants	1,268	118
Survivable crashes	59 percent	97 percent
Fatally injured occupants	953 (216 in survivable accident)	27 (23 in survivable accident)
Seriously injured occupants	228	65
Minor/none injured occupants	87	27
Fatally injured who would have survived with shoulder harness use	75%	65%
Seriously injured who would have benefited from shoulder harness use	88%	77%
Seriously injured who would have benefited from energy-absorbing seat use	34%	24%
Shoulder harness available	40%	32%
Shoulder harness use (if available)	40%	45%
Shoulder harness overall use	16%	14%

The longitudinal acceleration and velocity changes for 20 of the 39 accidents are shown in Figure 11. Because of missing data, such as impact velocity, or unusually long slides after impact, some cases were only partly usable. As shown, the upper limit of the range of acceleration loads in these survivable accidents is 30 to 35 G's and the upper limit of the range of velocity changes is 60 to 70 feet per seconds. Two other cases had velocity changes of over 80 feet per second. They are not plotted here because they were not typical cases. In one case the airplane remained suspended in trees; in the other, the impact was vertical and was non-survivable for the front seat occupants because of crushing.

Based on the extent of airplane damage and injury severity, the Safety Board believes that velocity changes greater than 60 feet per second approach the upper limit of survival in today's small airplanes. Shoulder harnesses in the most severe cases did not prevent occupant from contacting the instrument panel and airframe crushing began to compromise liveable space.

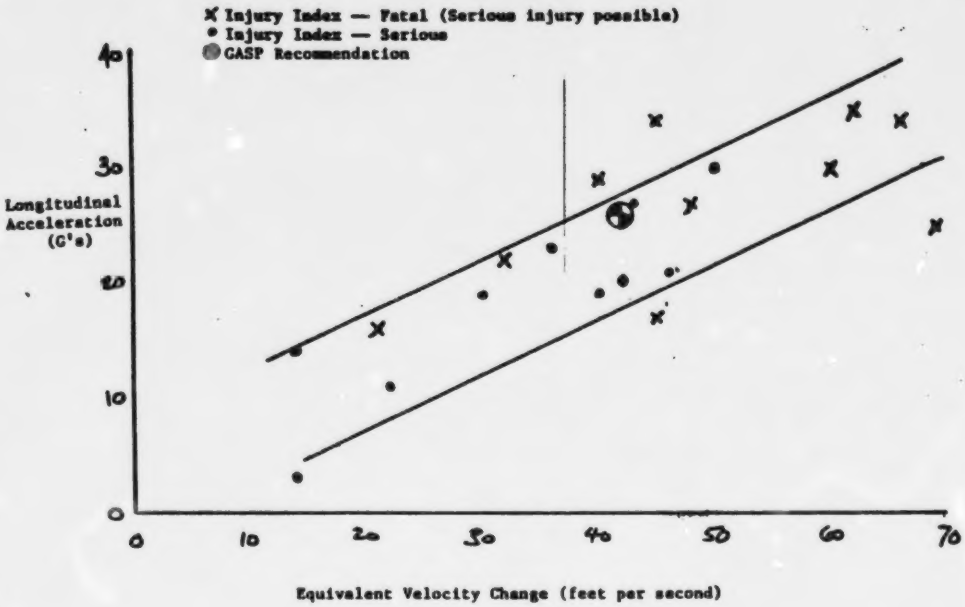


Figure 11. Longitudinal Acceleration and Equivalent Velocity Changes of Survivable Accidents

In the vertical direction acceleration loads and velocity changes were calculated for 12 of the 39 accidents (Figure 12). The upper limits approach 25 to 30 G's and 50 to 60 feet per second. The acceleration points connected with vertical lines are of interest. These two cases represent occupants in energy absorbing seats. In one case, the seat stroked about 6 inches, effectively increasing the occupant's stopping distance and thus decreasing the airframe to occupant acceleration level from 24 G's to 18 G's.

In the other accident, both front seats stroked their full travel of about 12 inches. The 180 pound occupant's acceleration level was decreased from 36 G's to 18 G's. The seat did not bottom out and thus it safely dissipated the energy generated by the mass of the occupant. The other occupant, a 270 pound individual, sustained fatal spinal/skull injuries when his seat bottomed out against the cabin floor, creating a large acceleration spike. Thus, the weight of the occupant is an important factor in the amount of protection that is afforded by energy absorbing seats.

The investigations of these accidents uncovered many problems in occupant crash protection which stem from long-standing design practices and the inadequacies built into the federal aviation regulations. For instance, the seat/restraint systems of modern general aviation airplanes, while generally greatly exceeding current design requirement, are not capable to structurally withstand the crash loads encountered in the upper severity range of accidents. Other problems encountered are seat attachment designs, lack of energy absorbing capability, lack of stroking distance, inadequate design of seat pans and a lack of periodic seat pan inspection and maintenance. Also, equipment added to seats contributed to failures and injuries. Thus, the small items and details that are often overlooked, like storing fire extinguishers in the seat's stroking spaces, adding oxygen equipment high up on the seat back, repairing a rip found in a seat pan with a household stapler, become the difference between injury and sometimes death and walking away from an accident.

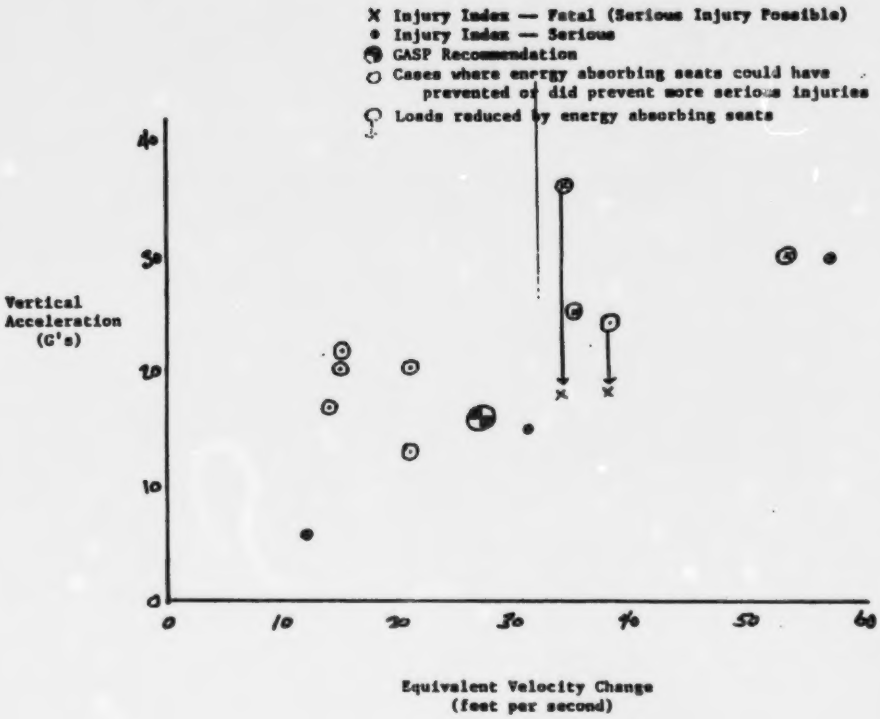


Figure 12. Vertical Acceleration and Equivalent Velocity Changes of Survivable Accidents

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Finally, let me quickly comment on the General Aviation Safety Panel (GASP) and its work in airplane crashworthiness.

The GASP was a high level study group formed from a broad civilian cross section of the general aviation community which was convened at the invitation of the administrator of the FAA, to look into a number of safety issues concerning this segment of aviation. In February 1983, the panel called for the mandatory installation of shoulder harnesses on all seats and to provide a means for collecting meaningful accident data on the effectiveness of seat restraint and harnesses and to compare such real world data with experimental results in order to provide a basis for creating design criteria.

Since the Safety Board had been gathering such real world data for its own study objective since the beginning of 1982, the Safety Board approached the general aviation airplane manufacturers as well as the FAA with a proposal to cooperatively resolve the technical stumbling blocks that had plagued past efforts to secure crashworthiness improvements in airplanes. This proposal was acted upon favourably and the GASP was reconvened.

Beginning in July 1983, the panel held a series of meetings with representation by the Safety Board, FAA, NASA, and airframe manufacturers among others. About a year later it forwarded a proposal to the FAA that defined the standards for seat and seat restraints, including requirements for the dynamic testing of seat/restraint systems to 26 G's at 42 feet per second in the longitudinal direction and provisions for energy management at 16 G's and at a velocity change of 27 feet per second in the vertical direction.

As shown in Figure 11, the GASP criteria fall in the middle of the longitudinal acceleration loads and velocity changes measured in the real-world accidents that formed the basis of the Phase III study. However, we believe that occupants of accidents with higher velocity changes would still receive substantiated benefit from seat/restraint systems designed to the GASP standards. Also, the GASP standards were designed to provide reasonable design requirements which could be met without excessive design penalties and costs.

The vertical GASP design requirements are compared to real-world crashes in Figure 12. The test load requirements proposed by GASP were purposely kept lower than optimum because of limited underseat stroking clearance in typical general aviation airplanes, especially in the rear seats. The load requirement and velocity change would ensure that at least some energy management design had to be incorporated in seats without forcing some airplane designs from the market.

Thus, Safety Board believes that the GASP proposal represents on good compromise, in light of costs and other design considerations.

To sum up, the Phase III study concluded in part, that:

1. Acceleration loads and velocity changes of 30 to 35 G's and 60 to 70 feet per second, respectively, in the longitudinal direction are the upper limits of survival for occupants of modern general aviation airplanes if properly restrained. In the vertical direction, acceleration loads of 25 to 30 G's at velocity changes of 50 to 60 feet per second are survivable but loads on the occupants must be limited to a lower level to prevent crippling injuries to the spine.

2. The GASP proposal must be viewed as minimum occupant protection design standards.

3. The practical limits of survivability in GA airplane accidents are governed by the type of seat/restraint systems used and the capability of the fuselage to withstand acceleration loads without uncontrolled collapse.

4. Head impact into the instrument panel often cannot be precluded. The head injury criteria (HIC) test, as proposed by GASP, therefore, is an important test criteria.

CONCLUSIONS
PHASE III STUDY

1. The accidents in this study were severe, but survivable, general aviation airplane crashes.

2. Acceleration loads and velocity changes of 30 to 35 G's and 60 to 70 feet per second in the longitudinal direction are generally survivable.

3. Acceleration loads and velocity changes of 25 to 30 G's and 50 to 60 feet per second in the vertical direction are generally survivable but the loads experienced by the occupants must be limited to a lower level to prevent crippling injuries to the back and neck.

4. The impact severities (angles and speeds) of the cases in this study closely match the impact severities of the NASA crash tests.

5. The current seat design requirements of 9 G's forward and 3 to 6 G's downward are inadequate.

6. The practical limits of survivability in general aviation airplane crashes are governed by the type of seat/restraint systems used and the capability of the fuselage structure to withstand acceleration loads.

7. Based on the results of this study, the GASP recommendation for a dynamic seat/restraint system test to 26 G's and 42 feet per second velocity change longitudinally appears to be reasonable and appropriate.

8. The GASP recommendation for a dynamic test seat/restraint to 19 G's and 31 feet per second velocity change vertically represents a minimal level of protection, but many occupants will be protected in seats designed to this standard. If the manufacturers also were to use available stroking distances effectively (and thus exceed the GASP requirement), most occupants will be protected in survivable accidents.

9. Many occupants in airplane accidents would derive substantial benefits from seat/restraint systems designed to GASP standards, even if the impact loads were more severe than the prescribed test loads.

10. Head impacts into the instrument panel cannot be precluded, even with properly designed restraint systems. The GASP requirement for the use of a Head Injury Criteria (HIC) test is important, if head impact to the panel is predicted during dynamic testing.

11. In the accidents analyzed as part of this study over 1/2 of the seats became detached in severe but survivable accidents. Current design requirements call for seat feet to withstand only very low side loads. Floor warpage also causes excessive stresses and separations in the feet of seats that cannot conform to the warpage.

PHASE III CONCLUSIONS

12. Study data indicate that shoulder harnesses are not being used to the fullest extent, even when available. Only crewmembers are required to wear them for takeoff and landing, and many crewmembers fail to do so. In other cases, the occupants released the shoulder harnesses while enroute and forgot to put them back on when an emergency arose.

13. Shoulder harness use can reduce the lapbelt loads, preventing many internal organ and pelvic injuries.

14. Shoulder harnesses should not be used to meet the 9 G longitudinal static load requirement for the entire occupant restraint system. Instead, each seat/lapbelt system should be required to restrain the occupant to 9 G's, i.e., the protection of a shoulder harness should be additive.

15. Energy-absorbing seats are necessary to prevent many of the spinal injuries that occur in survivable accidents.

16. Seatpan design requirements are needed to ensure that occupant loads are carried by proper structure. Seatpans should have rip- stop capabilities and should be designed so that they do not collapse catastrophically.

17. For most seats, add-on equipment should be prohibited because the added weight degrades the protection capability of the seat/restraint system.

18. Energy-absorbing seats, lapbelts, and shoulder harnesses should be designed as an integrated system so that the maximum advantage from each system can be gained.

19. Unique features of some airplane seat/restraint designs can contribute to the failure of the systems at loads that would otherwise be tolerable. For example, seatbelt attachment cables have been shown to be the first element to break in some airplanes. Simple actions to install larger diameter cables would improve the seat strength in these airplanes.

20. Available stroking space must be efficiently utilized and not covered over with flooring and cabinetry materials.

MR. McLAREN: Thank you very much Mr. Walhout for an excellent summary of those findings.

I neglected to open the floor for questions after Mr. Tucker's presentation, so I think I had better do that now, and open the floor to a few questions if we can take, perhaps, five minutes, if there are any questions for either of our two speakers.

MR. ROD LEE: So that everybody does not get away for coffee real early here - we can't let Gerry off the hook. I want to be clear, Gerry, on the recommendation with respect to seat restraint.

The testing, as I understood it from what you said, that was to be done, was dynamic testing on the seat restraint, which makes a tremendous difference, in my view.

Now, can you remind me of the existing requirement for 9-g? Is that dynamic or static?

MR. WALHOUT: That is a static requirement, yes, now in the Federal Regulations.

MR. LEE: Thank you.

SPEAKER: Could you restate the recommendation, Mr. Tucker, that related to suggesting or recommending installation, where practicable, of aircraft type - I think I missed an aspect of it - please? Did you limit it to just the front seats? That is really what I wanted to now.

MR. TUCKER: Front seats, yes.
[PAUSE]

MR. McLAREN: Well, if there are no further questions, we will adjourn now for a coffee break, and we will be reconvening at 10:30. Thank you.

SHORT RECESS:

UPON RESUMING:

MR. McLAREN: The next speaker after the coffee break was to have been Dr. Huey Carden of NASA Langley, and, unfortunately, due to another commitment he was unable to be here. So, instead, he was able to send us two films to be shown on some of their work. The first one has sound. It is a short film. The second part does not have sound, but Mr. Richard Chandler has agreed to narrate the silent part. And since Mr. Chandler will be following the film by his own presentation, I thought I would introduce him to you now.

Mr. Chandler has conducted research concerned with protection against crash injury for over 30 years. He began this work with the United States Airforce at Holloman Airforce Base, New Mexico, in 1955, where he first provided engineering support for the aeronautical Research Laboratory under the direction of Colonel John P. Stapp, a pioneer in research of human tolerance to impact.

He later served as Chief of Biodynamics Research at the Laboratory, and was responsible for directing impact tests to define human tolerance and to demonstrate the performance of crash injury protection systems for use in aircraft, automobiles, and space vehicles.

He joined the Office of Vehicle Research Systems Research at the National Bureau of Standards in 1958 to do research in human impact and restraint systems for use in automobiles.

He joined the Federal Aviation Administration in 1970 to become Chief of the Protection and Survival Laboratory at the Civil Aeromedical Institute in Oklahoma City, where he has specialized in seat and restraint system research, and has provided guidance for programs in evacuation, cabin safety, protective breathing equipment, survival, and human measurement.

Richard Chandler is currently Supervisor, Protection and Survival Research Laboratory at the FAA Civil Aeromedical Institute in Oklahoma City, and in his presentation he will be talking on general aviation seats and restraint systems: performance criteria and dynamic test methodology.
So, first, could we show the film now, please?

Film: Small Airplane Crash Dynamics Testing at NASA Langley - Langley Research Center, NASA Commentary of First Film:

"Crashworthiness means how well the airplane can protect its occupants from injury should a crash occur.

To get a true test, missing components are replaced by comparable weights, and fuel tanks are filled with water for weight and balance.

To measure accelerations that would be felt during a crash impact, instrumented dummies ride in the passenger seats. The plane is crashed on concrete and dirt at speeds of 60 miles per hour and above. They hit the ground from varied impact angles and altitudes.

To understand the impact of crashing on concrete, as compared to crashing on dirt, the same plane operating under the same conditions, is used to test for crash survivability.

These tests give engineers a better idea of what happens to an airframe during a crash. From this knowledge they can develop better methods for predicting structural response during impact. By applying this knowledge from twin-engine aircraft crashes to all general aviation aircraft, both government and industry researchers benefit; and more important, evaluating energy absorbing seating restraint concepts should lead to improved occupant protection."

MR. RICHARD CHANDLER: (FAA, Civil Aeromedical Institute): Let me first confess that I have not seen the film you are about to see. So this will be somewhat of an ad hoc narration based on my observation of those things I think you will find important.

Second Film: Small Airplane Crash Dynamics Testing at NASA Langley Being Shown

The NASA program, as the narrated film said, was initially constructed to look at structural crashworthiness, and, indeed, early in the review cycle of their program, I noted that they had not included interiors, or occupants, or seats,or restraints, and objective to that in the sense that the occupant mass would certainly change the response of the structural system.

So they added seats and restraints in response to my criticism but they added them in the best way they could. But the seats you see, and the installations you see, are not necessarily those that the manufacturer of the airplane would have supplied or did supply, but they were installed by NASA; so they may be better, they may be worse, they may be just the same, but they were not necessarily the manufacturers seat. I mentioned that because, to me, one of the interesting things will be the seat occupant restraint systems and their reaction in these crashes.

General Aviation Seat and Restraint Systems: Performance Criteria and Dynamic Test Methodology

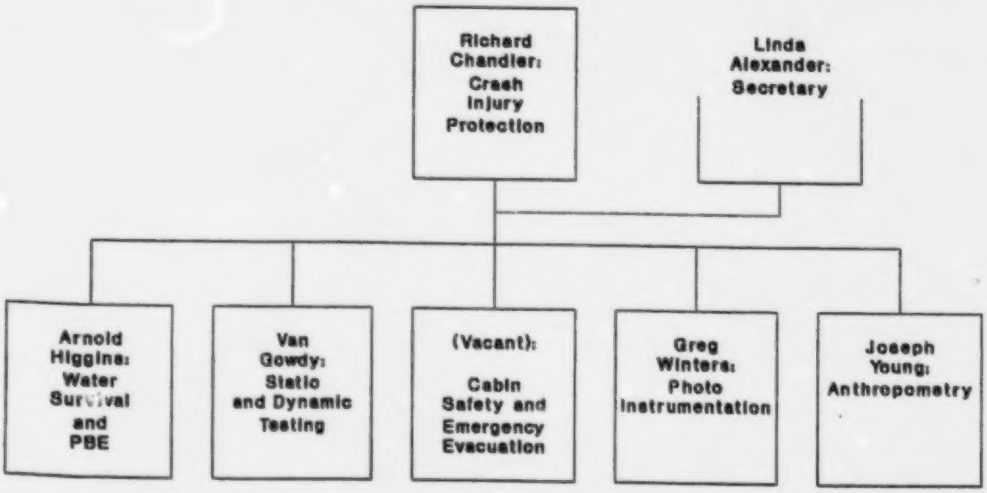
I would like to make available to you some handouts so that you could make marks on them, and there are some slides.

There are two handouts. One will be copies of the slides I will be showing. The handout with the small print is a front page copy of several references that we have not necessarily authored in our laboratory, but we have had significant input to; and there are references pertaining to the overall role activity in the recent crashworthiness program that we have conducted.

Now could we try the first slide, please?

Slide 1

Civil Aeromedical Institute
Protection and Survival Laboratory



Richard Chandler: Crash Injury Protection

Linda Alexander: Secretary

Arnold Higgins: Water Survival and PBE

Van Gowdy: Static and Dynamic Testing

(Vacant): Cabin Safety and Emergency Evacuation

Greg Winters: Photo Instrumentation

Joseph Young: Anthropometry

This tells you more or less what I am going to talk about, and I would like to point out that we are dealing with our second line of defense in this meeting.

The first line of defense must be accident prevention - and airworthiness has been mentioned before (and rightly so); we spent a major amount of our effort on that. When that line of defense fails us, we are left with a crash, and this new technology of crashworthiness.

Now this is a technology that has been developing over the past 40 or so years, and my talk on recent work will begin with my arrival at the Protection Survival Laboratory at the Civil Aeromedical Institute, at CAMI, in Oklahoma City.

For those of you who are not familiar with our laboratory, this is about how it is structured. Arnold Higgins is the Scientist who is in charge of the water survival work and protective breathing development. Those of you who are active in the Joint Canadian, British, French and American U.S.A. Studies on Passenger Protective Breathing Equipment have probably met Dr. Higgins; he is our representative in that work area. He also is responsible for progress in research on water survival techniques, both single and multiple occupant floatation systems - Van Guardi works very closely with me, and is sort of following in my footsteps relative to static and dynamic testing of seat and restraint systems, and will have more to say about that area as time goes on.

Our current cabin safety emergency evacuation unit is without a test scientist. Don L. Poward, who previously headed up our cabin safety area, is now in Washington with the FAA, and so we are looking for somebody with experience in that area. It is a very active area concerned with maintenance of the cabin safety data bank, and the conduct of emergency evacuation research in our evacuation simulator and with the conduct of periodic cabin safety workshops attended by international participants.

We have two more or less, support units: photo instrumentation plays a very important part in all our work, and, of course, physical anthropometry is important, because, in essence, our laboratory deals with the interaction of people and their emergency equipment in the emergency; so people are important to us.

I sort of supervise this whole mess; it is about an 18-person operation, so we are not a huge laboratory.

I came there in 1970, and, as you may have heard in the introduction, I came there with interest in dynamic testing and interest in applying the technology that had been developed by the other crash-oriented services, including the National Highway Traffic Safety Administration, to safety aircraft; and I found out that the system was not ready for it.

Now, could we have the next slide, please?

Slide 2

Technical Approach for Improving Seat/Restraint System Crashworthiness

- **Facility development ... develop a low cost facility capable of dynamic testing of civil aircraft seat and restraint systems.**
- **Cooperative testing ... the learning curve. Industry supplies the seat and restraint systems, we do the testing. Industry learns what dynamic testing can do for them, we learn about the performance of real seat and restraint systems under dynamic conditions.**
- **Develop test methods. Cooperative testing with other Federal Agencies (DOD, NHTSA, NASA) lets us evaluate their test procedures, and modify them for use with civil aircraft systems.**
- KEEP A LOW PROFILE!

R. F. Chandler, January, 1986

So in this area there is a multi-phased program. The first thing I had to do was to develop a low cost facility to do the work. We had very minimal facilities at CAMI twenty or so years ago, which really could not produce a very controlled environment.

Low cost was important to us in order to demonstrate that this testing procedure need not be an expensive procedure, and one that could be adopted by a manufacturer if they so chose. It was also important to us because we never got any facility dollars to develop a facility, so, basically, we had to do it ourselves.

So this work we will be talking about was developed on minimal type facilities - important, when you consider the cost of dynamic testing.

The second prong of our approach was co-operative testing. This was to build a learning curve with us and with the industry. The situation that we faced in the early seventies was one of a galvanized industry, an industry that had been galvanized by repetitive bashing in the product litigation courts, because of resumed crashworthiness deficiencies. The galvanizing creating a defensive attitude, and the lack of open-mindedness, if you will, as to what could be done. Basically, this resulted in a sort of status quo situation that, obviously, in every body's mind was going to change; and what we did, was to begin a co-operative program with industry so we could begin to show them what dynamic testing was really all about, and that we, the FAA, would learn just what were the real limitations and what were the feasible changes that could be made to existing practical real hardware.

Remember, now, we are talking about a program that began in the 1970's.

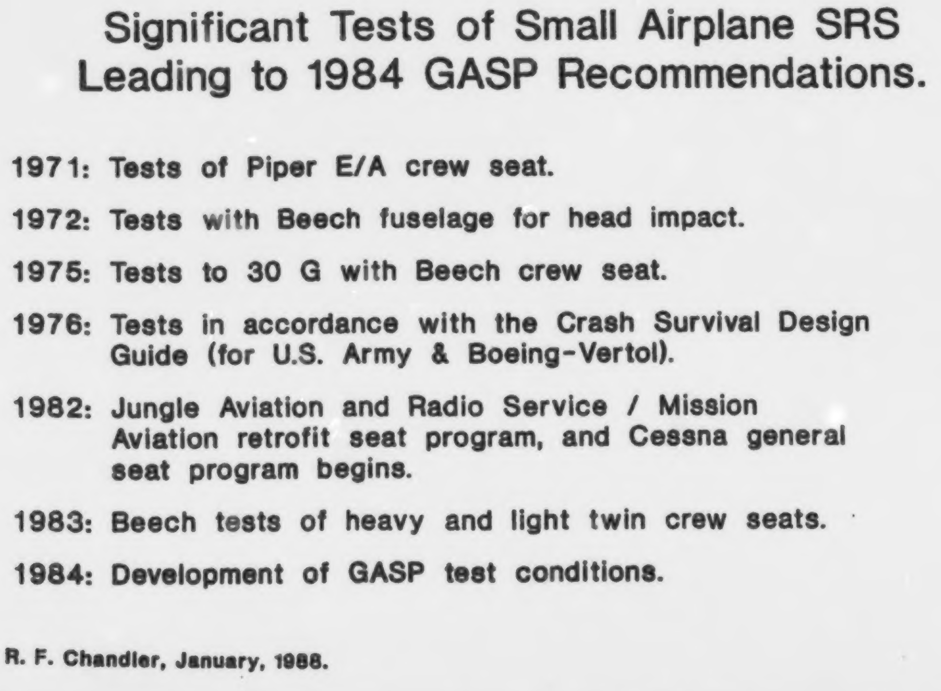
We also entertained co-operative testing with other Federal Agencies, primarily the Department of Defense, the Highway Safety people and NASA, to get their technology, so that it could be adopted towards the role of civil aviation, and, in particular, the crash survival design guide, which has already been, I think, mentioned - this survival design guide provided the basic guidance for military helicopter crashworthiness, and was subsequently used by us for the civil aviation systems.

Our work with MITSA, in particular, allowed us to evaluate the crash injury criteria; because, when we are talking about crashworthy seating and restraint systems, we are really talking about the end point - that is, the crash-injury protection. We have switched over mentally from building something that does not break, which has been the traditional end point in seating and restraint system design, to something which protects the occupant in a crash: a significantly different end point. It is one that cannot be done simply by doing a straight forward elementary level stress analysis on your structure; it is a rather involved procedure.

Our fourth, and final prong of this program was to keep a low profile. As you can see, this whole profile was based upon co-operative work between people that might be sensitive to front headline type disclosures of all sorts of things that were going on. So we have purposely not run to the report file, detailing every test we made, and, in particular, we have tried to promote progress rather than sensationalism in this type of activity.

Let us look at the next slide and see how we started and what progress we made.

Slide 3



Significant Tests of Small Airplane SRS Leading to 1984 GASP Recommendations.

1971: Tests of Piper E/A crew seat.

1972: Tests with Beech fuselage for head impact.

1975: Tests to 30 G with Beech crew seat.

1976: Tests in accordance with the Crash Survival Design Guide (for U.S. Army & Boeing-Vertol).

1982: Jungle Aviation and Radio Service / Mission Aviation retrofit seat program, and Cessna general seat program begins.

1983: Beech tests of heavy and light twin crew seats.

1984: Development of GASP test conditions.

R. F. Chandler, January, 1988.

Our facility accommodates about 150 tests per year. So, obviously, I have left a lot out of the slide. There were a lot of other things happening which I wouldn't bore you with: these are the high points.

Our first co-operative test program in 1971 was with an energy absorbing seating developed by Piper. So in the industry, 20 years ago, there were already moves towards crashworthiness seating systems. The big problem that everybody faced was one of definition: what was crashworthiness? When did we know when we were there? How could we define the end point, the test environment? All those things were undecided. These were things which could not be unilaterally decided by anybody, particularly by the manufacturers, because they would never do it good enough - in the litigation courts, at least.

So it took a co-operative effort; it took a long term development program.

In 1972, early in the program, we were doing our first test with Beech Aircraft, looking at head impact. Those of you who know your history know that Beech was one of the pioneers in crashworthiness development, going back to the early 1950's. They maintained a continuous active interest in this, and readily accommodated our offer of co-operative testing. We have had many significant programs with them, including the one in 1975, where we modified a Beech Musketeer crew seating system, and successfully tested at impact levels, dynamic testing now with occupants up to 30-g's.

Now a 30-g impact is a very significant impact. It is going to hurt. The basic philosophy of crash-injury protection is, one to reduce the level of injury or fatalities. Hopefully, we can reduce serious injury, and hopefully we can move down to the minor category; and our minor injuries, hopefully we can move down to the none at all type category.

So it is a push towards lowering, rather than eliminating injuries.

The 30-g crash would hurt like crazy, if you were to survive, but, I think, it is a fairly significant step forward. That was done with a full cabin section, incidentally, so we could also evaluate the impact. And you may have noticed, from the NASA films, that a restraint system does not lock you in with iron-clad jaws into your seating position; there is still a lot of flaying; there is still a lot of movement within the cabin, and there can still be expected secondary impact with the cabin interior.

I recently - just last week - attended a meeting with the military people on crashworthiness. It was brought out at that meeting that acceleration injuries, per se, are not the injury causation problem that we are fighting. It is secondary impact injuries with the interior.

Earlier studies at CAMI indicate that most injuries were distributed: about 30 per cent to the head, 30 per cent to the chest, and the rest to the torso spinal column, arms, legs, these are almost always secondary impact injuries - impacts with the interior.

Pure acceleration injuries are very, very rare.

The 1982 events I think are particularly significant for those people who are considering retrofit; because of the Jungle Aviation and the Mission Aviation program was, indeed, a retrofit program. These people operate a fleet of aircraft, and because of the type of operation, they concluded they wanted to improve crashworthiness. They are a Mission Service and literally operate out of the collection plate, so they have very limited funds for this program, but they undertook it upon themselves to develop a fleet modification, a retrofit program to improve crashworthiness. They did a few things wrong; they did a lot of things right; but they moved ahead, demonstrating that it can be done if the motivation is there and if a few dollars are there.

The other significant program was the beginning of a major program on seat development by Cessna Aircraft. We began a large series of tests, which ultimately resulted in the energy absorbing integrated seat restraint system for the Caravan aircraft, and this was undertaken in 1982, before the beginning of the general aviation safety panel work.

Now, that program, in particular, gave a lot of background to the General Aviation Safety Panel to demonstrate what could be done from practical, reasonable technology.

In 1983, another similar program was undertaken with Beech, looking at the heavy and light twin-engine aircraft crew seats - all leading to the work in late 1983 and late 1984 with the General Aviation Safety Panel.

May I have the next slide, please?

Slide 4

The General Aviation Safety Panel
GASP 1: Enhanced Crash Tolerance

- Formed at the request of FAA Administrator Helms in 1982.
- Has broad representation of the general aviation community under Chairmanship of Jack Olcott, editor of Business and Commercial Aviation magazine.
- Formed technical working group for crashworthiness in 1983.
- Issued recommendations for enhanced crash protection for small general aviation aircraft (<10 pax) in May, 1984:
    - Two dynamic tests at increased loads.
    - Floor deformation.
    - Injury criteria based on head injury, chest injury, and spinal column compression force.
    - Lap belt and shoulder harness position on the body.
    - Structural integrity of seat-restraint system.
    - Flight/ground operational loads with 215 lb occupant.

R. F. Chandler, January, 1988

Okay. The General Aviation Safety Panel, which I will refer to as GASP-one to differentiate it from the work done by GASP-two, the fuel systems panel, that Steve Soltis will be talking to you about in a moment, was actually formed as a result of an FAA administrator Helm's activity in 1982 - and Gerry Walhout has already given you some background on this.

The Panel is headed up by Jack Alcott, a masterful chairman, who was able to keep a rather diverse group headed in the right direction and managed to beat out a concensus out of this diverse group.

The technical working group for seat restraint systems crashworthiness was, as Gerry said, formed in 1983 - I believe it was July of 1983 - and by May of 1984 the recommendations had been made to the FAA.

So this was a group that moved ahead fairly rapidly. Within one year they made probably the most significant recommendations on civil aviation seat restraint systems; but the most amazing thing is that we reached a concensus. It was a diverse group and there was a lot of head bashing that went on, and a lot of compromise. I am reminded of the old saw that a camel being a horse that is designed by a committee, which implies that the camel is something of a less than perfect animal.

In a sense this is a camel designed by the General Aviation Safety Panel. It is certainly not perfect, but let us realize that the camel provides a very good means of transportation, and when it gets down to having a work beast, I would rather have a camel designed by the Committee than I would have the thoroughbred race horse, which looks very nice but does not carry much of a load.

This is a camel. It does not look very nice, but it will carry one heck of a load for you.

I did some very major changes in our state of the art, and let us also be relatively frank about it: even if the FAA managed to fumble on this for a long period of time, in a de facto sense this has become the new standard for seating restraint systems, and a concensus like this cannot go unnoticed by the entire community.

What it did provide for are two dynamic tests. Now these are dynamic tests, as Gerry said, up to 26-g's in the forward facing direction with a lateral yaw component, and up to 16-g's in the vertical direction.

It included dummies which simulated the occupants, not body blocks. It includes a capability for measuring the dummies' responses and interpreting injury criteria.

But before we get there, let's notice the second important thing I listed in my chart there. It includes floor deformation. Typically, the static test loads that we have been abiding by for all these years are done on a rigid floor simulation.

You should have noted in the NASA films, and, certainly, if you have looked at many crashed aircraft, that when aircraft crash they bend. That is one of the inherent problem of crashing; you bend your airplane up, and the floor is deformed.

One of the major problems, in my viewpoint, in maintaining seat-to-floor integrity has been the problem of floor deformation, and the fact that a floor does not remain rigid in a crash, but they do deform.

The GASP recommendations do include provisions for floor defamation as part of the test procedures, and it is a very important provision, and one which must be accommodated with some ingenuity in design.

We have included as part of our pass-fail criteria not only structural integrity, but injury criteria - injury criteria based on head injuries. Here, we have adopted the head injury criterion developed by the National Highway Traffic Safety Administration and now used for demonstrating performance in automobile crashes and automobile crash-injury protection. It is certainly not perfect; our camel is not a race horse yet, but it is certainly a functional means of evaluating head injury.

It also includes a measure of test injury based upon restraint system load, upper torso restraint load on the premise that the restraint system would be, and should be, the primary device applying load to the chest. This is a little bit different from the automotive application, where they have looked at blunt injury to the chest primarily from the steering column as one of their injury problem areas.

And, finally, something else that is unique to the GASP recommendations. We have a measure of spinal column compression, to look at vertical loading in the body. Because of the lightness and relatively low mass of civil aviation seats, we were not able to use the classical airforce DRI dynamic response index, so we correlated DRI with measurements made in the lower spinal column with the dummy, and used the spinal column compression force as our injury criteria.

This does two things for us. It allows a direct measure of spinal column injury. It also allows us to influence the position of the restraint system - shoulder straps pulled down on the shoulders also contribute to the spinal column injuries; and, quite frankly, if you misplace your shoulder belt anchorages, you will not be able to meet the injury criteria based on the spinal column loads.

So we are influencing the design in a number of ways.

One of the other things we have influenced is that you may not see too many diaphragm fabric or rubber diaphragm seat pans, because we have not had anybody successfully pass these tests with a fabric or rubber diaphragm type of seat pan.

Those of you who have been in the crash investigation business will probably say, "Halelujah! It's about time!" And we have, I think, gone a long way to eliminate this potential problem area.

We have identified the lap belt and shoulder harness position on the body. I know, classically, we think that the lap belt should go around the hips, but would you believe that there is no requirement anywhere in the regulations that it is to be placed on the hips; and we have had retrofitters who have wanted to fit the lap belt under the armpits, and, strictly speaking, that is within the regulatory allowables.

So, with this criteria, we have at last positioned the restraint system on the body. We have also demonstrated, in a very functional and realistic way, the structural integrity of the seat restraint system.

Now, I will be the first to admit that once you know the loading conditions on a piece of structure, like the seat restraint system, you can eventually involve a static loading procedure to give you that same loading condition. What I am saying is, that once you know how it breaks, you can break it statically.

What this technique does is give is a universal technique which will evaluate the structure, without having to go back and tweak and modify, change your body block static procedure - a very complicated thing that we find very difficult to do-in practice.

Finally, one of the recommendations dealt not with the crash event, but with flight ground operational loads, where the 215-pound occupant, rather than the 170-pound occupant, was identified.

All in all, I think this gives us a significant movement towards doing things right in crash-injury protection. Now, this is available, not only in the recommendations of the General Aviation Safety Panel, but has been put forth in a notice of proposed rule-making.

Let us look at the next slide now.

Slide 5

Additional New Information Available For Improved Seat-Restraint Systems

- Advisory Circular on Injury Criteria
- New static test method for torso restraint system anchorages.
- Advisory Circular on torso restraint system installation.
- SAE Aerospace Standard 8043, Torso Restraint System adopted as a TSO.
- Advisory Circular on dynamic test procedures.

R. F. Chandler, January, 1988

Those documents have not been the only documents that have been brought forth in this arena. We have an advisory circular out on injury criteria which, hopefully, identifies the fact that injury criteria and voluntary human tolerance are two different things. We are dealing with injury criteria, something we do not expect to voluntarily expose ourselves to in the GASP recommendations; we are dealing with injury, not voluntary exposure.

We have procedures out for new static test measures for torso restraining system anchorages. There had not been any uniform test procedures for testing upper torso restraint system anchorages before, and indeed one recommendation implied that a 200-pound pull on the anchorage point would suffice. Well, obviously, a 200-pound pull does not suffice.

We developed new techniques using new body blocks, new pull procedures, to give a systems check.

Now, these items are referenced in that little list of reduced sized handouts I gave you. So, in case you are interested in any of these, you can follow through.

Perhaps as important as anything, there is a new SAE Aerospace Standards, 8043, that has been adopted by the FAA as a new TSO for restraint systems.

This TSO was evolved to provide a means of evaluating the restraint system, so the restraint system user, the person putting the restraint system in an aircraft - could be relatively sure that it will pass the recommendation, the test called out in the recommendations of the General Aviation Safety Panel.

It, in itself, does not provide fully adequate evaluation of the restraint system, but it is intended to be later used in a system test with the seat, the restraint, the occupant under dynamic conditions. This SAE standard is some 30 pages long. Those of you who are familiar with the few pages that have been our previous guidance, will recognize that this is a significant step forward in defining all of the things that the restraint system must do, and, hopefully, this will avoid some of the problems we have seen with the broken anchorage, worn webbing, and so on and so forth.

In process is an advisory circular to detail dynamic test procedures, the notice of proposed rule making tells you what you should do, but it does not tell you how to do it. Those of us who have been in the dynamic testing business for a few years know that you can structure a dynamic test to do all most anything you want it to do. You can do the same thing with static tests, too; I guess we all know that.

The advisory circular on dynamic test procedures is intended to give guidance as to how to do it right, so that everybody can get the same answer, or, if not right, at least consistently.

The next slide, please?

Slide 6

Work Still To Be Done For Improving Seat-Restraint Systems

- **Development and general availability of low cost restraint system kits for aftermarket installation. These systems should be approved, and preferably dynamically tested to demonstrate performance.**
- **Development of non-destructive test to verify the strength of attachment fittings for aftermarket installation of restraint systems.**
- **Development of non-destructive inspection techniques for seat and restraint systems, especially for non-metallic components (webbing, stitching, seat pan diaphrams or straps).**
- **Development of satisfactory low cost replacements for non-metallic seat pan diaphrams or straps.**
- **Development of test procedures for evaluating emergency locking retractors (inertia reels).**

R. F. Chandler, January, 1988

Now, finally, I have given you some ideas. We are not through yet. Let me assure you that the saying that all the easy things were done a long time ago, applies again. None of the easy things are left; all the work that is left to do is hard.

But these are some of the hard things that I think can be done, that need to be done - certainly not in an all-inclusive list, but some of the highlights.

Certainly if we are talking about after market or retrofit installation, one of the problems is the unavailability of a reasonably priced installation kit. Prices range upwards from $800.00 to $1,000.00 for a restraint system installation; those are certainly a detriment, particularly when you consider that the hardware itself is probably all-told less than $100.00.

We need a low cost after market kit available, one that is, hopefully, approved, and can be installed with little fuss on the part of the aircraft owner; and, also, preferably one that has been dynamically tested. Now, that may be tough. There are a lot of systems out there that have not been dynamically tested. I would like to think they all work, except that if you have seen all the second, third and fourth tries to develop the system that has gone through our laboratory, you will know that the best intent of the first try proved well statically, may not be a very good restraint system.

Non-destructive testing and inspection techniques are also very much needed in our system. How do you really verify the adequacy of a restraint system anchorage in an aircraft without destroying the aircraft? Tough question! Obviously, you pull on it. How much? Well, did you notice how the anchorage points tend to deform in the NASA films? Sometimes they bend your aircraft. We are going to have an awful lot of very bothered aircraft owners if they come up with bent aircraft as a result of our demonstrating the adequacy of a newly installed anchorage fitting. Somehow, this has to be accommodated.

Non-destructive inspection techniques for seat restraint systems, particularly for non-metallic components, I think, are very much needed.

I hoped Gerry would have shown some of the NTSB findings on the seat pan failures; because there are a lot of rotten seat pans out there; they have rotted over the years in service, and they are falling apart. We need to have inspection techniques that we can identify these and, hopefully, my next thought there is replace them with some sort of low cost metallic seat pan.

Webbing seat restraint systems are not very well inspected. You have probably flown on many aircraft, and you may have noticed that the webbing was rather furry, and perhaps cupped and perhaps worn along the edges. Gentlemen, Ladies: That's webbing that is worn out; it has lost a good percentage of its strength and it will begin to fail on you sometime in its lifespan. You can wear out webbing simply by passing it through its normal lifecycle; and right now there are no inspection techniques that are being used to identify this and have it replaced. This is certainly something that needs to be thought about.

Finally, the last of the DOT is one that was missed in the new TSO and the new Aerospace Standards - a development of test procedure for evaluating emergency locking or tractors.

I pointed out in the NASA film the long play out of webbing from inertia. Right now, we don't have good test procedures to demonstrate the performance of those devices.

The new Aerospace Standard, the new TSO, did something remarkable. It changed the lock-up level from nominally 3-g-'s down to 1 1/2-g's. We are fiddling with tradition here; it has been 3-g's forever, but it can play out, and you can get serious injuries with a 3-g play out on your restraining system.

So the new Aerospace Standard, the new TSO, has changed that.

We have also gone to multi-mode locking reels, in many instances; that is, where the reels are locked not only by strap play out, but also by vehicle deceleration. Those of you who have tried to tug on the reels on your automobile, have probably found that you could tug until you are blue in the face and they wouldn't lock up. Well, they are not broken; automobiles, by and large, don't lock by pulling on the webbing. They lock by the vehicle crashing, and the crash itself locks them up.

In many applications, for example, side facing seats, heaven forebid - you have to use reels that lock up by some technique, other than reel, than webbing play out, if you are going to get early lock up in the cycle.

I just alluded to one of my favorite things that should be done, but nobody has had the initiative to do it; it is not on my list, so you can blame it on me verbally, but I never wrote it down. For God's sake, can't we do something about side facing seats? I know of no good crashworthiness restraint system for side facing seats, and we still permit them; and yet I have not had anybody, with any type of restraint system, that I would like to sit in while undergoing a crash environment of the magnitude outlined by the General Aviation Safety Panel. The problem is not the ingenuity of the designers, the problem is a lack of concentricity of your body - your legs swing around, they are very hard to restrain your body in a side facing orientation.

I think that's my last slide. I am also out of time.

Thank you.

MR. McLAREN: Well, thank you for an excellent presentation.

Our final presentation for the morning's session will involve a change in subject to the fuel system. Stephen Soltis will be giving us a presentation on general aviation fuel system: crash dynamics.

Mr. Soltis is currently employed by the Federal Aviation Administration as the National Resource Specialist in crash dynamics.

In this capacity, he is actively involved in the Agency's engineering and development programs and respective rule-making actions concerning crash dynamics.

Before joining the FAA, Mr. Soltis served 24 years as a structural design engineer and structures analyst on rotary and fixed-wing aircraft.

He holds a Bachelor's Degree from St. Louis University and a Masters from California State University at Long Beach, both with specializations in engineering.

He is also an active member of the SAE S-9 Cabin Safety Provisions Committee and the American Helicopter Society.

Mr. Soltis?

General Aviaton Fuel System: Crash Dynamics

MR. STEPHEN SOLTIS (Federal Aviation Administrator): Thank you.

I would like to discuss a little bit some of the deliberations of GASP-2. It concerns primarily one of the GASP-2 task assignments that dealt with evaluating crash-resistant fuel systems, particularly bladder cells, and effect that they may have on the aircraft should they be installed.

Let me start with some comments on GASP. I think we have heard quite a few today, so I will not belabour the issue.

GASP was initially formed to develop recommendations to improve general aviation safety; was formed, as was mentioned earlier, at the request of the FAA Administration in the summer of 1982, and the Administrator at that time was Mr. Lynn Helms.

SLIDE 1

The General Aviation Safety Panel (Gasp) Formed To Develop Recommendations For Improved General Aviation Safety

FORMED AT THE REQUEST OF THE FAA ADMINISTRATOR

REPRESENTED A BROAD CONSTITUENCY FROM THE GENERAL AVIATION COMMUNITY

- RESEARCH
- REGULATORY
- MANUFACTURERS OF G/A PRODUCTS
- G/A USER GROUPS

Early in 1983, they submitted a report to the FAA that put forward several recommendations concerning means of improving general aviation safety.

Areas addressed were: areas of operation, weather, pilot training, crash impact protection.

SLIDE 2

GASP Identified Two Areas Where Recommendations For Improved Crash Tolerance Might Be Developed

SEAT STRENGTH / OCCUPANT IMPACT PROTECTION

FUEL SPILLAGE / POST-CRASH FIRES

The area of crash impact protection was further addressed by some of the workings of the subsequent GASP panels - GASP-1 and GASP-2.

Primarily, GASP identified two areas where a recommendation for improved crash tolerance might be addressed. One was the seat strength in the occupant impact protection area, and that was discussed quite thoroughly by Mr. Chandler. The second area dealt with fuel spillage and post crash fires.

Both of those are quite different technologies, and when we initially tried to address both of them simultaneously, we found it was nearly impossible, since different specialists are involved in each of the disciplines therefore GASP elected to address these issues in a two-stage approach.

GASP-1 addressed the seat strength and occupant impact protection standards. As was mentioned earlier, the seat dynamic performance standards were developed. Pass, fail performance criteria were also defined, and GASP recommendations were submitted to the FAA during the Small Airplane Airworthiness Review Program - and that took place in October, 1984, in St. Louis. Their recommendations were published as an NPRM, and is NPRM 86-19 in the Federal Register on December 12th, 1986.

SLIDE 3

GASP I Addressed Seat Strength And Occupant Impact Protection Standards

SEAT DYNAMIC PERFORMANCE STANDARDS DEVELOPED

PASS / FAIL PERFORMANCE CRITERIA DEFINED

RECOMMENDATIONS SUBMITTED DURING THE FAA SMALL AIRPLANE AIRWORTHINESS REVIEW PROGRAM

GASP-2 addressed fuel spillage and post crash fires. Their deliberations began in July, 1984.

SLIDE 4

GASP II Addressed Fuel Spillage And Post-Crash Fires

GASP II STUDIES IDENTIFIED :

FREQUENCY OF FUEL SPILLAGE AND POST-CRASH FIRES

FREQUENCY OF OCCUPANT INJURIES AND FATALITIES ATTRIBUTED TO POST-CRASH FIRES

SOURCES OF FUEL SPILLAGE AND POTENTIAL IGNITION SOURCES

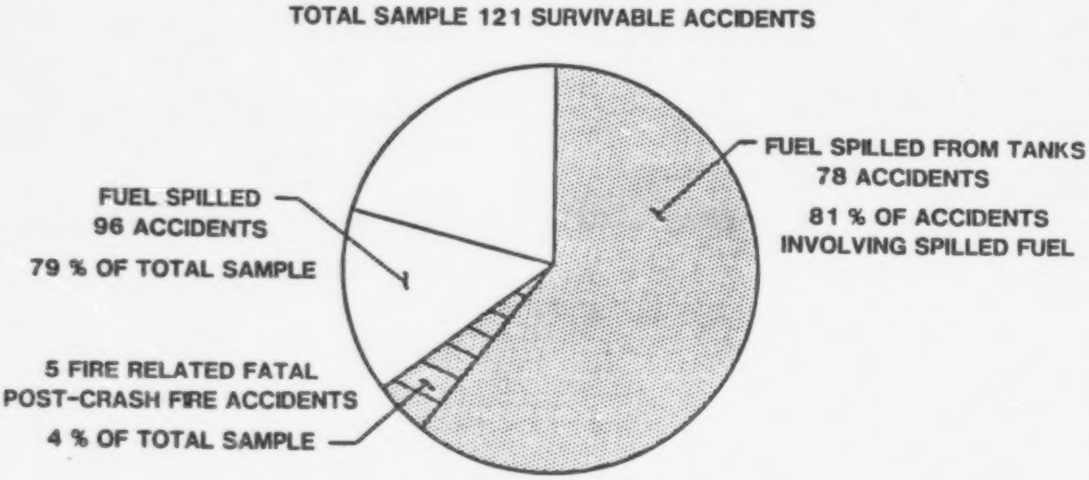
The GASP-2 studies identified the frequency of fuel spillage in post-crash fires. They identified the frequency of occupancy injuries and fatalities attributed to post-crash fires. They addressed some of the sources of fuel spillage and potential ignition sources.

Regarding fuel spillage, as we found out in some of the studies being conducted by the FAA Technical Centre, which were recommended by the GASP-2 panel - we found that fuel spillage frequently occurs in survivable accidents.

You can see here for the total data sample that was evaluated, out of 121 survivable accidents, fuel spilled in 96 of those accidents - 79% of the total sample.

SLIDE 5

Fuel Spillage Frequently Occurs In Survivable Accidents



Out of those 96 accidents, fuel spilled from fuel tanks in 78 of the accidents. So 81% of the accidents actually involved fuel spilling from the fuel tank.

In that data sample, five fire related post-crash fire accidents were found, and they represent about 4% of the total sample.

As noted here, spillage from fuel tanks is a relatively common occurrence, and we wanted to evaluate what are the consequences of placing crash-resistant fuel tanks in general aviation aircraft.

So, along that end, a study was directed and initiated to provide some quantitative data to address some of those issues; and that quantitative study addressed the potential penalties such as fuel volume reduction; what weight penalties might be incurred; the study was primarily addressed to new certificated aircraft, but retrofit to current production aircraft was briefly addressed.

SLIDE 6

Study Directed to Provide Quantitative Data

FUEL VOLUME REDUCTION

WEIGHT

NEWLY CERTIFICATED AIRCRAFT

RETROFIT INTO CURRENT PRODUCTION

The study included a wide range of aircraft sizes and configurations. It included high-and-low-winged aircraft, single and twin-engined aircraft, and both piston and turboprop aircraft.

SLIDE 7

Study Included A Wide Range of Aircraft Sizes and Configurations

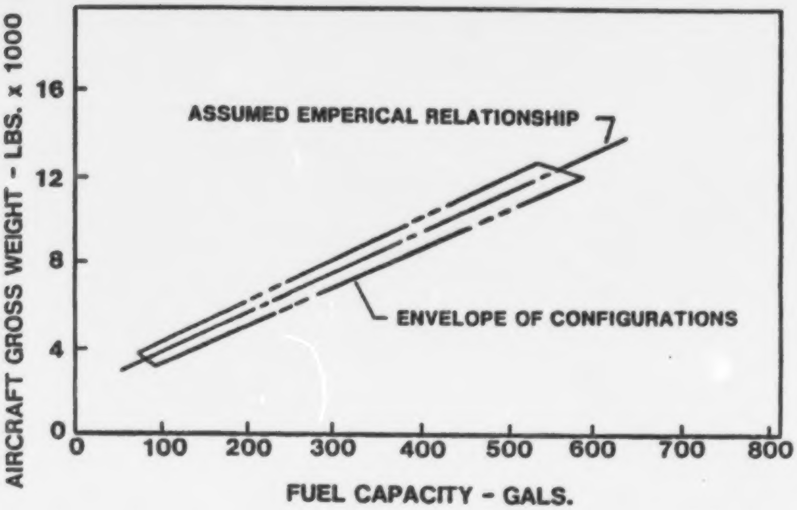
HIGH/LOW WINGED

SINGLE/TWIN ENGINED

PISTON/TURBOPROP ENGINED

SLIDE 8

A Range Of Aircraft Configurations Was Evaluated



This figure depicts the range of aircraft configurations that were evaluated, and it includes a weight range of a little under 4,000 1,250-pound weight limit, and the associated fuel capacity associated with the aircraft to 12,500.

We first looked at the potential fuel volume reduction that might be if you installed store bladder cells in those particular aircraft.

SLIDE 9

Potential Fuel Volume Reduction Assessed

BLADDER CELL ITSELF

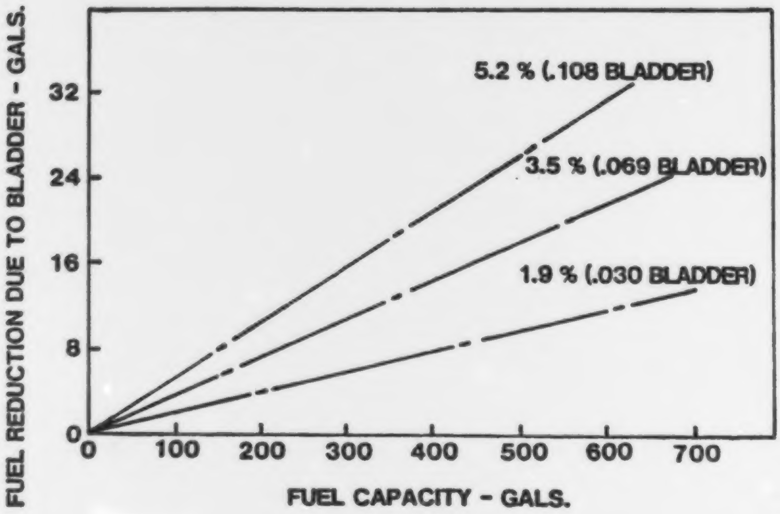
FUEL REDUCTION ASSUMED FUNCTION OF:

- **FUEL CAVITY SURFACE AREA**
- **BLADDER CELL WALL THICKNESS**
- **BLADDER CORNER RADIUS**

Looking at the bladder cell itself, - the fuel volume reduction was assumed to be a function of the fuel capacity surface area, the bladder cell wall thickness, and the bladder cell corner radii - an inch corner radii was used in this particular study. All of those parameters affect the fuel volume reduction.

SLIDE 10

Fuel Reduction Due To Bladder vs Fuel Capacity



SLIDE 11

Potential Fuel Volume Reduction Assessed

FUEL CAVITY LINER

ESTIMATE BASED ON A FEW TYPICAL INSTALLATIONS

MOST RATIONAL DESIGN APPROACHES

VOLUME REDUCTIONS FOUND IN THE ORDER OF 6.5 TO 8.5 PERCENT OF FUEL SYSTEM CAPACITY

Using those parameters in evaluating some of the installations that might be feasible in the range of aircraft we have just looked at, the fuel reduction due to installation of a bladder and its installation - the fuel volume reduction was defined with respect to the fuel capacity of the fuel system itself for different aircraft and for a range of different bladder cells.

Where the .030 inch wall thickness bladder cell is the typical weight that might be found in current general aviation aircraft, the .069 is more representative of what many feel might be a good bladder cell for civil aircraft applications. The .108 thick bladder cell is more typically used in military crash-resistant fuel system applications.

And you can see for the .069 thick bladder cell, you will incur perhaps a three and a half per cent fuel volume reduction penalty should that bladder cell be installed in general aviation aircraft.

SLIDE 12

Resultant Fuel Volume Reduction

BLADDER CELL THICKNESS - IN.	RESULTANT VOLUME REDUCTION*
.030	8 to 10 %
.069	10 to 12 %
.108	12 to 14 %

* PERCENT OF FUEL CAVITY CAPACITY

SLIDE 13

Resultant Fuel Volume Reduction

SYSTEMS RECEPTIVE TO BLADDER CELL INSTALLATIONS

AIRFOIL THICKNESS RATIO 16% OR GREATER

FUEL CAVITY LESS THAN TOTAL AVAILABLE WING VOLUME

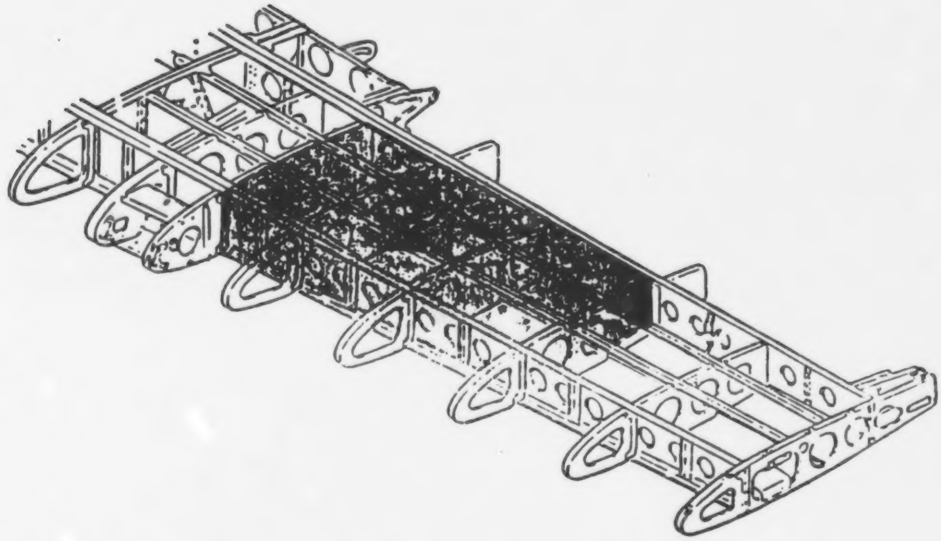
FUEL CAVITY REASONABLY ACCESSIBLE

TYPICAL OF MANY AIRCRAFT/FUEL SYSTEM CONFIGURATIONS

The potential fuel volume reduction was also addressed with respect to the fuel cavity liner.

Fuel cavity liners are installed for, one they minimize chafing, should a bladder be installed in a fuel cavity; they are also used to control unusable fuel.

SLIDE 14



We have made some estimates based upon a few typical installations, and looking at some of the more rational design approaches for installation of fuel cavity liners, and we found that you can expect fuel volume reductions in the order of six and a half to eight and a half per cent for a typical fuel system.

Combining the fuel volume reduction which might be expected from both the bladders and the liner installations, we have determined the resultant fuel volume reduction. You can see, as shown here in this figure for the .069 thick bladder, which we believe is representative of a good bladder for a crash-resistant fuel system for civil application; you might expect a ten to 12% reduction in fuel volume.

The fuel volume reduction relationship, which we have just addressed, is typical of systems that are receptive to bladder cell installations; and by that I mean, aircraft that might have winge airfoil thickness ratios of 16% or greater, and the fuel cavity in those aircraft is less than the total available wing volume, and the fuel cavity is reasonably accessible. And those features are typical of any aircraft fuel system configurations found on many general aviation aircraft. And what that really means is a fuel system that might look something like this - might have a wing structure which might look as depicted on the figure, and you are placing fuel in a portion of the wing where it is readily feasible to install fuel in that area; and the orange-shaded area might be a typical installation.

There is actually a second class of aircraft fuel system configuration that also needs to be investigated, and they are aircraft which might have an airfoil thickness ratio of 12 to 13%, where the fuel cavity encompasses most of the total available wing volume, and includes area where bladder cell installations are not really feasible.

SLIDE 15

Resultant Fuel Volume Reduction

SECOND CLASS OF AIRCRAFT/FUEL SYSTEM CONFIGURATIONS

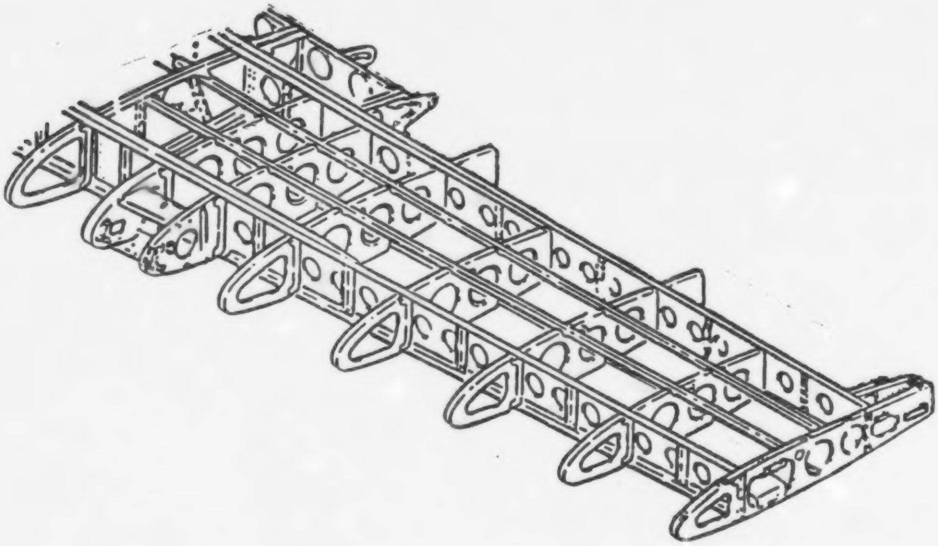
AIRFOIL THICKNESS RATIO 12-13 %

FUEL CAVITY ENCOMPASSES MOST OF TOTAL AVAILABLE WING VOLUME

AREAS WHERE BLADDER CELL INSTALLATION IS NOT FEASIBLE

VOLUME REDUCTION ESTIMATED IN THE ORDER OF 20 to 35 %

SLIDE 16



And looking at those types of systems, volume reduction estimates could be in the order of 20 to 30% - say 35%; and a fuel system such as that might look like this, where the sort of lavender-colored area would be the area where fuel is carried in the wing - more of an integral fuel tank, and you can see some of the trailing and leading edges might be more difficult to install bladders in those areas, and, maybe, possibly in the in-board or tip areas. The tip areas, being very thin, would be a difficult area to install a bladder, and possibly in the in-board area you might start interfering with landing gear support structures, and things of that nature. We also looked at fuel system weight assessment, and we looked at some of the weight penalties which might be incurred due to the installation of the fuel cavity liner. The fuel bladder itself, and possibly the changes that might have to be incurred to the airframe structure.

Looking at the fuel system weight assessment, we are looking at only the fuel cavity liner. The weight of the liner itself was assumed to be a function of the fuel cavity surface area, where we assumed that 50% of the area would be lined, whereas the remaining 50% of the fuel cavity is really more of a natural liner, and would not necessarily require the addition of a liner.

SLIDE 17

Fuel System Weight Assessment

FUEL CAVITY LINER

FUEL BLADDER CELL

AIRFRAME STRUCTURE

We have looked at liner materials of aluminum, sixteen-thousandths of an inch thickness, and fibreglass of twenty-thousandths of an inch thickness, where we felt experience showed that those materials were adequate for their intended purposes as fuel liners.

Using those parameters, fuel cavity liner weights were established. You can see here for the sixteen-thousandths aluminum fuel cavity liner, that you can experience probably about eight-hundredths of a pound per gallon weight cavity associated with installation of that liner; and, correspondingly, for a fibreglass liner, you might see seven-hundredths of a pound per gallon weight penalty because of the installation of that fuel cavity liner.

SLIDE 18

Fuel System Weight Assessment

FUEL CAVITY LINER

ASSUMED FUNCTION OF :

FUEL CAVITY SURFACE AREA

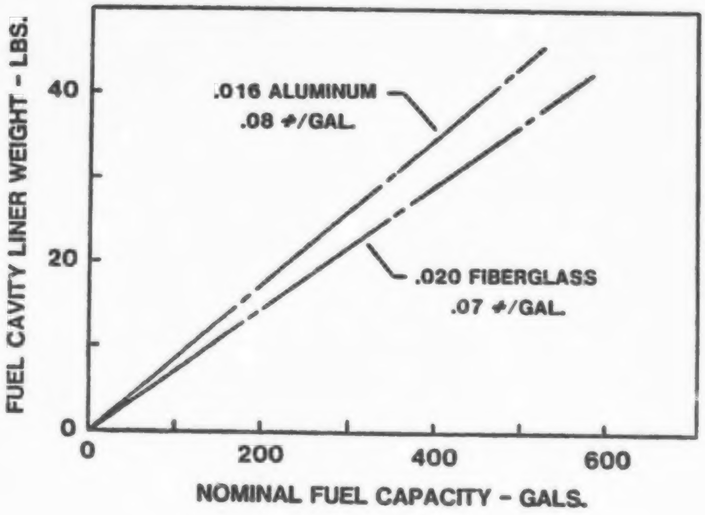
50% SURFACE AREA LINED

LINER MATERIAL

ALUMINUM	.016 IN.
FIBERGLASS	.020 IN.

SLIDE 19

Fuel Cavity Liner Weights Were Established



We have also looked at the weight assessment - weight penalties that might be associated with the installation of the fuel bladder cell itself. Again, we looked at three different fuel bladder weights: the 30 thousandths, the 69 thousandths, and the 108 thousandths bladder wall thickness weights.

SLIDE 20

Fuel System Weight Assessment

FUEL BLADDER CELL

BLADDER FABRIC MATERIAL WEIGHTS

DEPENDENT ON SURFACE AREA

.030 In.	.149 Lbs/Ft^2
.069 In.	.330 Lbs/Ft^2
.108 In.	.562 Lbs/Ft^2

METAL INSERT/FITTING WEIGHTS

DEPENDENT ON FUNCTION/LOCATION

EMPERICAL RELATIONSHIP ESTABLISHED

3.5 LBS PER BLADDER CELL

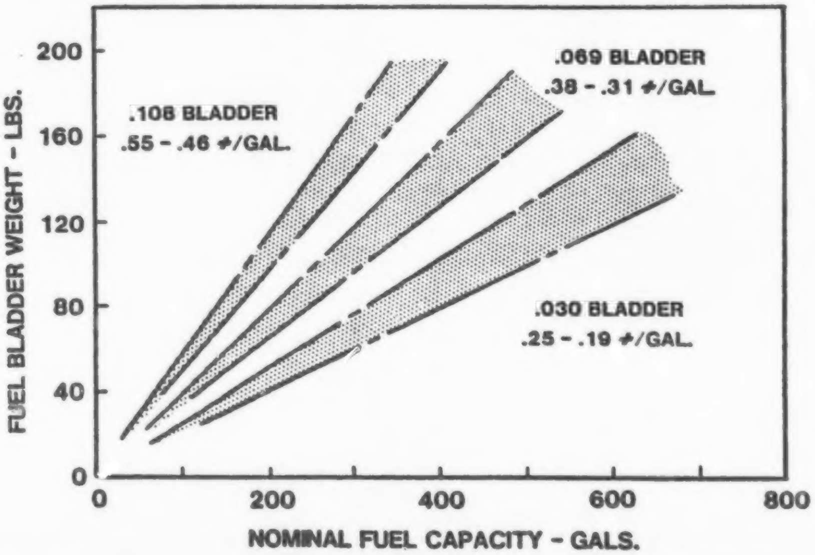
ESTIMATES CORRELATE WITH KNOWN IN-SERVICE BLADDER CELLS

We also made an assessment of the weight of the metal inserts and the fittings that would be associated with those particular bladder cells; and the metal weights are really dependent on the function and location of the particular tank, but we were able to establish some empirical relationships that say, more or less, that perhaps three and a half pounds per bladder cell might be the weight of metal inserts and fittings associated with a particular bladder cell. That estimate reasonably correlates well with some known in-service bladder cells.

Then, using those parameters, again we were able to define the fuel bladder weights as a function of bladder thickness, and relate that to fuel cell capacity.

SLIDE 21

Fuel Bladder Weights Were Defined As A Function Of Bladder Thickness And Fuel Cell Capacity



You can see here, again, for the .069 bladder thickness that you could incur a weight penalty of somewhere around 38 to 31 hundredths of a pound per gallon, should you install a fuel bladder of the .069 wall thickness in the fuel cavity.

You will notice a bound on the range here, and the lower range of the curve refers more to the first category of aircraft that we discussed earlier, which includes the thicker wing sections, the 16% thicknesses, the upper bounds of the curve, the heavier weight penalties more associated with the thinner or 12% thicknesses.

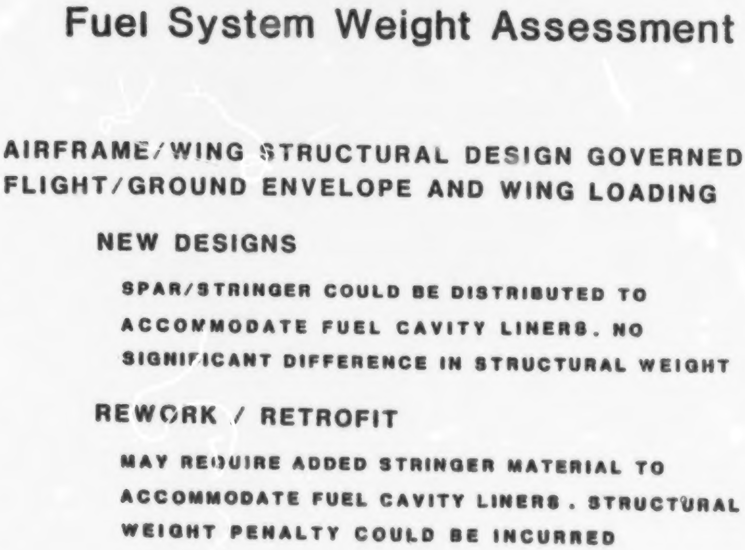
Again, looking at fuel system weight, we wanted to look at the airframe weight; and we found that the airframe wing structural design is really governed by their flight and ground envelope and the wing loading.

Those conditions really define the distribution of the bending material in the design of the wing, and not the design of the fuel system per say.

On new designs, the spars and stringers could be distributed to easily accommodate fuel cavity liners, and we don't feel there would be any significant differences in structural weights, should crash-resistant or any bladder cells be installed in new design aircraft.

On retrofit, re-work of current designs that might not have bladder cells installed, you might require some added stringer material to accommodate fuel cavity liners, and structural weight penalties could possibly be incurred.

SLIDE 22



Fuel System Weight Assessment

AIRFRAME/WING STRUCTURAL DESIGN GOVERNED BY FLIGHT/GROUND ENVELOPE AND WING LOADING

NEW DESIGNS

SPAR/STRINGER COULD BE DISTRIBUTED TO ACCOMMODATE FUEL CAVITY LINERS. NO SIGNIFICANT DIFFERENCE IN STRUCTURAL WEIGHT

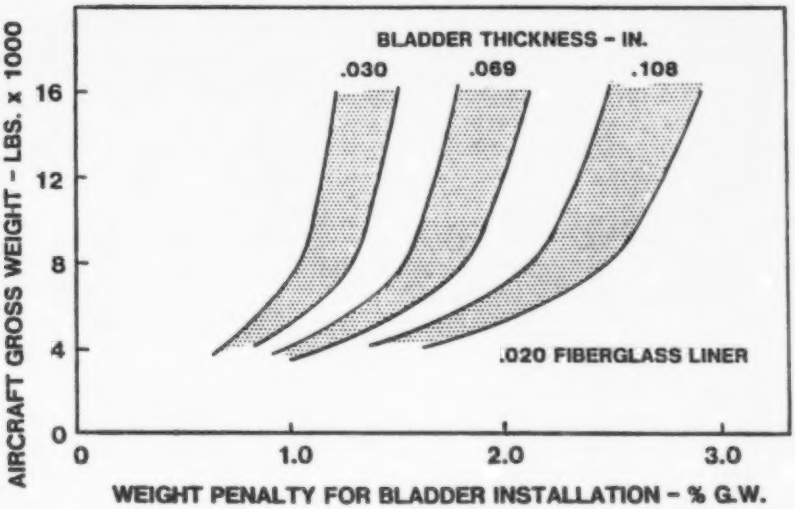
REWORK / RETROFIT

MAY REQUIRE ADDED STRINGER MATERIAL TO ACCOMMODATE FUEL CAVITY LINERS. STRUCTURAL WEIGHT PENALTY COULD BE INCURRED

Using some of the previous figures, we were able to define what weight penalties might be associated if fuel bladders were installed; and these relationships are a function of aircraft gross weight, and they define the gross weight penalty that might be associated with the installation of a fuel cavity liner for the three bladder weights that were again investigated - these curves are representative of the .020 inch thickness fibre glass liner; and, again, the bounds shown on these curves are representative of the 12% and the 16% airfoil thickness ratios. You can see for the 69-thousandths bladder cell that you might incur a weight penalty of roughly about one half per cent of the gross weight of the aircraft.

SLIDE 23

Weight Penalties Associated With Fuel Bladder Installations Were Defined



We have looked briefly at the assessment of the current design re-work or retrofit, and certainly you will incur a fuel volume reduction if you try to retrofit aircraft and you see the same type of fuel volume reduction that you would see with the installation of crash-resistant or fuel cavity liners as in new designs. And, as far as fuel volume reduction, you are certainly going to get a reduction due to the installation of a fuel cavity liner, and also due to the installation of the bladder cell itself. You will incur a weight penalty; you will increase the empty weight of the aircraft, and that could, perhaps, affect the pay load of the aircraft itself.

SLIDE 24

Assessment of Current Design Rework

FUEL VOLUME REDUCTION

- FUEL CAVITY LINER
- FUEL BLADDER CELLS

WEIGHT PENALTY

- INCREASED EMPTY WEIGHT
- PAYLOAD AFFECTED

Looking at the fuel volume reduction penalties, you could result in a significant operational penalty as far as range reduction. This, again, deals with re-work of current aircraft. And, for example, with 12% fuel volume reduction previously mentioned, that is associated with the installation of the 69-thousand inch bladder material, you could see a range reduction in the aircraft of eight per cent in some cases,and perhaps 13 or 14% for the majority of aircraft installations.

Assessment of Current Design Rework

FUEL VOLUME REDUCTION RESULTS IN SIGNIFICANT OPERATIONAL PENALTY, i.e., RANGE REDUCTION

EXAMPLE:

12% FUEL VOLUME REDUCTION ASSOCIATED WITH INSTALLATION OF .069 in. WALL THICKNESS BLADDER

RANGE REDUCTION

8% SOME CASES

13 - 14% FOR MAJORITY OF AIRCRAFT

Now, just briefly to summarize what this study has shown: we have been able to produce some estimates that develop relationships between aircraft gross weight and fuel capacity; we have been able to identify the fuel volume reduction that could be associated with fuel capacity, which are related to the installation of the fuel bladder installation itself, and due to the installation of the fuel cavity liner.

Summary / Conclusions

RELATIONSHIPS DEVELOPED TO PROVIDE ESTIMATES OF:

AIRCRAFT GROSS WEIGHT vs FUEL CAPACITY

FUEL VOLUME REDUCTION vs FUEL CAPACITY

DUE TO FUEL BLADDER INSTALLATION

DUE TO FUEL CAVITY LINER INSTALLATION

Summary / Conclusions (cont.)

ADDED FUEL SYSTEM WEIGHT

DUE TO FUEL CAVITY LINER

DUE TO FUEL BLADDER INSTALLATION

DUE TO AIRFRAME STRUCTURAL WEIGHT

AIRCRAFT GROSS WEIGHT
vs % GROSS WEIGHT PENALTY

We have looked at the fuel system weight penalties that could be associated due to the installation of the fuel cavity liner, and also due to the installation of the fuel bladder, and we have shown that airframe structure weight on new designs would be essentially unaffected.

We have made an estimation of the aircraft gross weight and the gross weight penalties which might be associated with the installation of crash-resistant fuel systems in general aviation aircraft.

We have mentioned that re-work of current designs would increase the aircraft empty weight or reduce the fuel volume and operational range of those aircrafts.

Summary / Conclusions (cont.)

REWORK OF CURRENT DESIGNS WOULD INCREASE THE AIRCRAFT EMPTY WEIGHT, REDUCE THE FUEL VOLUME AND OPERATIONAL RANGE OF THE AIRCRAFT.

THIS STUDY ALSO PROVIDED A QUALITATIVE FINDING THAT FUEL CELL BLADDERS COULD BE, AND ARE IN SOME CASES, INSTALLED IN SELECTED AREAS SUCH AS READILY ACCESSIBLE WING BOX AREAS IN THE WING ROOT OR IN ENGINE NACELLES WHERE IGNITIVE SOURCES COULD EXIST. THOSE INSTALLATIONS WOULD HAVE MINIMAL IMPACT ON AIRCRAFT DESIGN OR FUNCTION.

The study also provided a qualitative finding that fuel cell bladders could be, and in some cases, installed in selected areas, such as readily accessible wing box areas or engine where ignition sources could exist. These installations would have minimal impact on aircraft design or function.

Last, but not least, I would just like to mention that there are really two classes of aircraft fuel system configurations that were defined. You might recall the thin and thick airfoil configuration, and one which might be more readily acceptable to installation bladder cells where the other might not be; and, of course, cost-benefit analysis should address each class, if we are going to look at installation of these systems in general aviation aircraft.

Summary / Conclusions (cont.)

TWO CLASSES OF AIRCRAFT/FUEL SYSTEM CONFIGURATIONS DEFINED

- COST/BENEFIT ANALYSIS SHOULD ADDRESS EACH CLASS

CURRENT ACCIDENT DATA ANALYSIS DOMINATED BY FIRST CLASS

- A MARKED INCREASE OF WET CELL AIRCRAFT/FUEL SYSTEM CONFIGURATIONS MAY CHANGE OCCURRENCE OF FUEL SPILLAGE/IGNITION FOUND IN ACCIDENT DATA ANALYSIS

And some of the accident data analysis that we included in our evaluations that GASP-2 had utilized, were dominated by the first class of aircraft - they generally included bladder cells or metal tanks in the aircraft configurations themselves; and a marked increase in wet cell aircraft configurations may change the occurrence of fuel spillage and the ignition sources found in the accident data analysis that was used by GASP-2.

Now, these are essentially some of high points of one of the studies that were conducted as part of the GASP deliberations, primarily directed towards looking at some of the weight and volume penalties which might be associated with the installation of bladder cells in general aviation aircraft.

That review does not discuss the GASP-2 recommendations per se; it was just a task assignment as part of the GASP-2 working committee. They are part of an SAE paper that was published that goes into a little more detail on some of the items I have just touched on during my presentation here.

SUMMARY OF GASP II RECOMMENDATIONS

APPLICABLE TO ALL SMALL G/A AIRPLANES WITH LESS THAN 10 PASSENGERS

ADDRESS FUEL SPILLAGE AT JUNCTURES OF LINES AND CONNECTIONS

ADDRESS CRASH RESISTANT FUEL TANKS

FAA INVESTIGATE ADDITIONAL MEANS TO REDUCE FUEL SPILLAGE FROM FUEL TANKS

FAA PREPARE AN ADVISORY CIRCULAR TO IDENTIFY ACCEPTABLE MEANS OF COMPLIANCE

But, subsequently, GASP have made some recommendations that were forwarded to the FAA, and they were forwarded on December 31st, 1987. They are applicable to all small general aviation airplanes with less than ten passengers; they address fuel spillage at junctures of lines and connections; they address crash-resistant fuel tanks, and they recommend that the FAA address additional means to reduce fuel spillage from fuel tanks, and additional means maybe other means other than installation of fuel bladders. They also recommend that the FAA prepare an advisory circular to identify acceptable means of complying with some of the GASP-2 recommendations.

Looking at fuel spillage at junctures of lines and connections, addressed by GASP, GASP recommended that fuel spillage be restricted to eight ounces, and that the areas to be addressed to restrict fuel spillage would be areas of the wing fuselage juncture, the fuselage engine mount juncture, the juncture between tip tank and wing, and a dry bay area behind an engine, if used to carry fuel. These are areas that typically see relative motion between each other, and are areas that frequently would spill fuel as a result of that relative motion during an impact.

FUEL SPILLAGE AT JUNCTURES OF LINES AND CONNECTIONS ARE ADDRESSED

FUEL SPILLAGE RESTRICTED TO 8.0 OUNCES

WING/FUSELAGE JUNCTURE

FIREWALL/ENGINE-MOUNT JUNCTURE

JUNCTURE BETWEEN TIP TANKS AND WINGS

DRY-BAY AREA BEHIND AN ENGINE IF USED TO CARRY FUEL

The recommendations also include some definitions of the properties of crash-resistant fuel systems that were felt applicable for usage in general aviation aircraft. In essence, it recommended that they comply with MIL-T-27422B, Type II, Class (A), with the following exceptions, where the constant tear rate will be reduced from 400 foot pounds to a 200 foot pound; the impact penetration drop height of the five pound chisel would be eight feet; impact tear, the drop height of the five pound chisel shall again be eight feet; the average tear should not exceed one inch, whereas in the MIL spec I believe the drop height is ten feet, and the tear is half an inch.

The crash impact Phase 1 portion of the MIL spec was deleted. They deal more with component qualification test or material qualification testing; and the crash impact test of a fuel full sized production test cell is defined where the crash shell shall be filled to eighty per cent of normal capacity, the water and air removed, and a test cell shall be placed on a platform and dropped at a height of 50 feet without leakage after impact. The major change here deals with the drop height, where the MIL spec requires a 65 foot drop height.

PROPERTIES OF CRASH RESISTANT FUEL SYSTEMS ARE DEFINED

COMPLY WITH MIL-T-27422B, TYPE II, CLASS A EXCEPT:

Constant Tear Rate - The minimum energy for complete separation shall be 200 foot pounds.

Impact Penetration - Drop height of a five-pound chisel shall be 8.0 feet

Impact Tear - Drop height of a five-pound chisel shall be 8.0 feet and the average tear shall not exceed 1.0 inches

Crash Impact Phase I Deleated

Crash Impact Test of Full Size Production Test Cell
- The cell shall be fillled to filled to 80 percent of normal capacity with water and the air removed. The cell shall be placed upon a platform and dropped from a height of 50 feet without leakage after impact

That pretty much ends my presentation, and presents some insight on what the GASP-2 recommendations are.

Thank you for your attention.

MR. McLAREN: I think we have time for one or two questions for either of our two speakers of the latter part of the morning.

SPEAKER: (?) To Mr. Chandler, I am just curious as to whether you have any sense as to whether those regulations that you are putting forth, as to when they might filter through into the larger transport category type aircraft?

MR. CHANDLER: They use a parallel set of recommendations for the transport aircraft and Otis - 8611 aircraft, that was also actually out on the street first, and the comment period on that has also closed. And, as far as dates action on anything, I have long since given up trying to predict what the regulatory people will do - and there is one sitting two seats down from you.

MR. TANKESLEY: In regard to that question, the only thing I can tell you is that both of those notices have been developed in the final rules. One of the things that delayed ours slightly was a petition for an extension of the comment period, and when you get such a petition, you have to consider it, and that delayed all work on the resolution of the comments and the drafting of the final for about 30 to 45 days.

But both of those rules have been finalized and have been co-ordinated through the Washington office, and both of them were forwarded to the Secretary of Transportation on January 21st, of this year.

MR. CHANDLER: I will just make one comment perhaps in clarification of an item in Steve's presentation. When he showed you the survivable accidents that had fuel spillage on them, those were severe crashes, not just prop benders - but severe survivable accidents that did spill the fuel. So that was a selected set of accidents, not all survivable accidents.

SPEAKER(?): One thing I would like to address is undetected leakage. There is significant risk in undetected leakage that occurs with bladder tanks. Would you comment on that?

MR. SOLTIS: Well, I do not deny that there are several types of - I guess - upper penalties or things which might be addressed or need to be addressed with installation of bladder cells. They were discussed during the GASP-2 deliberation - the potential for chafing, breaking, leakage, and the installation removal and inspection of those tanks - they were discussed at some length. But the bottom line is, you know, the bladder is an effective container, and it does serve a purpose.

Now, nothing is perfect, and all we can do is to do our best in installing bladders and to try and minimize the negative effects, such as chafing, or wrinkling, or leakage that might be incurred by some of these bladders.

That might not be a good answer, but it has been considered and addressed during the GASP-2 deliberations - those concerns.

SPEAKER (?): Did those considerations take into account the case where an aircraft is operating to its limits, that is using full pay load and full range, such that when I see penalties of the order of 15% or so, to maintain that productivity I am going to have to do more landings and take-offs. Is there any net savings in those cases when I am exposing the aircraft to more landings and take-offs?

MR. CHANDLER: That is exactly one of the comments some of the participants in the GASP-2 panel had made, and I think you will find that issue addressed in the GASP-2 recommendations.

SPEAKER (?): One aspect, Mr. Chandler, one aspect that was not touched on was the nature of the fuselage structure that would affect the dynamic loading that would then go through into the seat structure, and thus to the occupant.

What I am alluding to here is the difference between the composite fuselage and a metallic fuselage. Is there a major effort under way in the FAA and other organizations in the States to get some handle on the qualification of these composite fuselages?

MR. CHANDLER: Yes, there are several programs under way. Some of them have already been accomplished, and perhaps you are familiar with the advanced composite aircraft program developed by the army for helicopters that is already completed and published.

But I think crashworthiness of composite structures is probably in its infancy at this stage of the game.

We are constantly learning new things about composite, and we have some general rules of thumb as to what we should or should not do, but I think it is premature at this time to think of, in the immediate foreseeable future, a development of any crashworthiness documents on composite aircraft structures. We are having enough trouble with maintainability and inspection, and all of those other things. There are programs, for instance, in the military, to look at composite structures, and, of course, there are numerous in-house R & D programs going on, looking at composite structures.

Crashworthiness is something that is particularly difficult, and I would not expect anything soon in that area.

MR. SOLTIS: I would like to add to that, if I may, please.

There is a joint program being initiated by the FAA in NASA which will address more thoroughly the crash impact response of composite structures; and there is a joint meeting, I believe, going on today or tomorrow, or something like that, in NASA, which is taking place at this current time period.

NASA has been able to obtain two or three composite airframes. These are from the airframe corporation who, I guess, has gone out of business. We are looking at what might be the best usage of those airframes in doing some crash impact testing very much like what you saw in the films earlier today.

So a program is in the initial stages of being structured along those lines.

MR. McLAREN: Well, I think we are running about 15 minutes behind schedule now, and I think we had better cut the questions off here, and there will be plenty of opportunity this afternoon to bring out other items.

I would like to thank the speakers in this morning's session for an excellent series of presentations, and an excellent short course in crashworthiness; and, in particular, I would like to thank our U.S. speakers for agreeing to come all this way and to share with us the results of their very extensive research programs.

Thank you.

LUNCHEON ADJOURNMENT

THE FUTURE FOCUS OF CANADIAN RESEARCH AND DEVELOPMENT AND REGULATORY ACTIVITY IN SMALL AIRPLANE CRASHWORTHINESS

MR. TORCK: Good afternoon ladies and gentlemen; Could I ask you to take your places, please.

Thank you very much.

The aim of this afternoon's panel's activity is, as stated in the Agenda, to define a future focus for Canadian R & D and regulatory activity in the small aircraft crashworthiness field.

To assist us in this phase of the process, we have selected six panelists, who have been requested by letter to make a statement on where and what they believe that focus for the R & D segment for small aircraft crashworthiness should be, at least in their view.

In that regard, if I might, I would like to thank at this time Mr. Chandler and Mr. Soltis for their particular remarks today, because they clearly identified a number of areas where they feel there is still a great deal of work to be done. In that vein they have in fact pointed, I guess, to some of the areas that we might be expanding our efforts on.

I do not intend to go through and do a full introduction of each of the panel members. Their individual CV's are under Section 2 of the Book that you have; and so, if you have not read them at this time, if you would do so as we go on, I would appreciate it very much.

I would like to introduce them very quickly, though. Our panelists consist this afternoon of Mr. Ron Hayman, who is the Director, Engineering Branch, for the Canadian Aviation Safety Board; Earsa L. Tankesley - I think most of us know him as Tank - Manager, Regulations and Policy Office Small Airplane Certification Directorate in the FAA; Dr. Fernando Cicci, Director Product Engineering, DeHavilland Canada; Dr. Rod Tennyson - Director, Institute of Aerospace Studies, University of Toronto, and Mr. David Heakes - our own Mr. David Heakes, Chief of Engineering Airworthiness, Transport Canada; and, finally, Dr. Gerry Marsters, Director of the National Aeronautical Establishment, it should be, if I remember correctly.

Without any further or additional comments, I would like to ask our panelists to begin; and in earlier discussions, I arm-wrestled Ron Hayman to the ground, and he has agreed to kick it off. What we will do is simply follow the order of the individuals as indicated on the Agenda.

So each of the panelists have been asked, in fact, to speak for five to eight minutes. We will go through the entire set of presentations or remarks, and at the end of that time we will then launch into our discussions.

We do not intend to build - if I may quote from someone - we do not intend to build a camel here; I think that came from Mr. Chandler. The camel exists, is carrying quite a load. What we want to do here for Canadian interests, is, I guess, more to point the camel in the direction in which we want him to carry the load.

With those opening remarks, I would like now to call on Mr. Ron Hayman. Ron, if you can kick it off, I'll appreciate it very much.

MR. RON HAYMAN (Director, Engineering Branch, Canadian Aviation Safety Board): Good afternoon, ladies and gentlemen.

From the perspective of the CASB, and particularly the Engineering Branch where we have perhaps more than most direct exposure to the results of aircraft accidents, our priorities for crashworthiness emphasis are clear, and correspond exactly with the statistical analyses on the subject. Clearly the greatest payback in terms of saving lives lies with improving the quality of seat restraints and this would be our first priority for a Canadian R and D focus and a rethink of the applicable regulatory activity.

To be more specific, our experience has confirmed that design changes which would preclude Murphy-type maintenance errors in installation of restraints, the quality of belt material, which appears to deteriorate strengthwise with time, and the strength of the seats themselves, are all good candidates for crashworthiness upgrading.

We continue to be plagued with other crashworthiness shortcomings, all of which can be correlated directly with loss of life in aircraft accidents: poorly designed latching mechanisms in doors preventing easy egress, cluttered cockpits, and in the area of post-crash survival, ELTs which refuse to operate when they are most needed.

Finally, the results of several recent accident investigations involving home-built composite aircraft have convinced me that we have much to learn about energy absorption qualities of new materials. We have already killed two pilots this year in amateur-built, composite structure machines, both accidents occurring as a result of construction faults. The number of these aircraft either flying of in various stages of construction highlights the need for good airworthiness inspection and assistance to our amateur "homebuilders" in the fabrication of composite structures.

MR. TORCK: All right, thank you very much.

Well now, Mr. Tankesley?

MR. TANKESLEY: Thank you, sir.

The subjects of our R & D and Regulatory activity in small airplanes is to be in focus, and I would like to give you the focus from my point of view, an account of my priorities. Of course, you can understand that everyone is interested in seats, and I notice there was one proposal which was finalized and sent to the Secretary's office - was my priority number one. Among my next priorities - my next two priorities are those same types of proposals for the commuter category type airplane. By the time we put this together there was no commuter category. As of right now there are two final rules in the secretary's office for transport and small airplane. There is a notice for 29 and 27 helicopters out with the same type of proposals, and so the commuter categories would be the one place where such proposals would have some progress - high priority to fill that gap.

My next priority, almost parallel with that, is the fuel system. Prior to working on these recommendations with the GASP panel, the GASP-2 panel, we did not get those in my office until the end of December; for some reasons they were a few weeks delayed and we have just had them long enough to start trying to work them into what the regulatory language should be and what the notice would be. I don't have a real handle on the final completion date, but it is one of our top priorities, to follow through and complete.

Another priority which I can't do much about is the notice stemming from the 23 review. It has other safety-related items in to and other recommendations, the cost of technology development in small airplanes, and that notice was completed, and as far as co-ordination, was sent to the Office of the Chief Counsel, and there is very little I can do to get the Chief Counsel to move on it; but it is one I keep working on and trying to move on.

Other areas I would mention some of the things that I have been working with the Washington office at the Technical Centre. A couple of little things involved new fuels for small airplanes. As you know we have approved several STC's and the development and use of automotive fuels; automotive fuels are starting to use more methane than ethanol, and we don't know for sure how those products will affect the fuel systems, and there is work being done on that at the Technical Centre, and there is also more of a push to use pure methane or pure ethanol systems in airplanes. We don't know enough about them. Both of those items could be directly safety related, particularly the single engined airplane: gets awful quiet when that one engine quits.

Another area that I see we need to pay attention to is the one we talked about somewhat this morning. We identified that NASA had a meeting on it and the Technical Centre also has an item about that - what happens with an all-composite airplane? We have had several projects on small airplanes directed to certifying the all-composite airplane, and the most noticeable is the Beech 2000, and that airplane is probably not too far away from certification.

One that has not been mentioned, and that is being actively worked on - it will affect transport, it will affect every aircraft operator, is the new RF environment that we are starting to find in the field; it, coupled with the avionics and the electronic systems that we are putting on the airplanes, can cause a very critical and hazardous effect. It has been reported or speculated that we may have lost several airplanes to this phenomenon and did not even know about it at the time it happened; but the RF (?) energy is a real threat and we have a person assigned to the committee that works with Washington and our other FAA offices, and other people working on this area, to try to get control over that so we know where we are going.

Right now we are proposing those types of systems we have tested to 200 micro-volts per meter as more or less an interim measure to insure that we have some protection. But there is some information out there that shows that in some frequencies we should be considering 6,000 volts per meter. There is a lot of difference between 200 and 6,000. We don't know yet, and we do not want to be unreasonable with unreasonable tests, but we also want to be sure we are safe.

Lightning is another area, with composite airplanes, and the development of requirements and acceptable test methods (I have a person that is working actively with an SAE committee and other directorate people, but we need to be sure that we are on top of lightning, and its effect on an all-composite airplane.

We know pretty much what lightning will do to a metal airplane, but we don't know what it will do and how it will affect the systems on particular on an all-composite airplane.

Another area - I don't want Jim to fall out of his seat here - another area I am concerned about is what happens to an airplane that goes in the water? The NTSB has made some recommendations about over water operations, and when it comes right down to it, I looked for data and background and for information, and I find I don't have any information one way or the other; I don't have any information that says, "Hey, you should do something regulatory-wise with over-water operations", or, "No, there is no reason to worry about it".

So I have asked, and we need to do some research there to find out what happens with an airplane when it goes into the water and is forced to land in the water, and to note for sure what we need to do - to be fair and have either not to propose any additional requirements, or no we don't need any, or to know what requirements we need to pursue, and then try to pursue those requirements.

That pretty much sums up what I see as our needs and some of the things we need to be concerned about.

MR. TORCK: Thank you very much.

Could I ask you just to reach back. You have given us quite a selection of areas in which work needs to be done, quite obviously. We have been trying to get an idea where the Canadian effort might better fit.

You have identified, in your discourse, that there are a lot of activities that the FAA is already engaged in.

Is there an area in those that you have spoken of where there is not too much effort from the FAA and where Canadian effort might best be concentrated? If there is, could you identify that for us?

MR. TANKESLEY: I am somewhat limited in this area because many of these requests are in our R & D research work in Washington, the Technical Centre.

But I do feel that one of the areas that is still pretty much immature as far as any activity in the agency, is over water operations and the water landings. This is something that we have identified as fairly new - and it is in fairly new NTSB recommendations; so, as of right now, I don't think we have moved very far in this area one way or the other.

MR. TORCK: In your view, that would be a very productive...

MR. TANKESLEY: And you have got a lot of water up here! I am a fisherman, I love to fish, and I know you have.

MR. TORCK: That is quite obvious, we do have an awful lot of water surface in the country, and it is maybe worth while for us to concentrate in that area.

But is this aimed at the airplane or at the operations?

MR. TANKESLEY: Both - I would say both, Jim; what happens to the airplane if it does happen to land in water - is one of the things we are concerned about. Will it float? Wouldn't it float? Will it float high enough for the people to get out, to be able to open the doors? If they open the door, will it just let the flood come in and cause it to sink?

There are so many questions that we don't know.

MR. TORCK: Okay, thank you very much.

Right next door to you - Doctor, would you mind taking the mike and identifying the focus from your point of view?

DOCTOR FERNANDO CICCI (Director, Product Engineering, DeHavilland Canada): Thank you very much, Jim.

First or all, I would like to congratulate the principals in organizing this Seminar and doing obviously very hard and very good work, summarizing for those of us who have not been into the crashworthiness of light aircraft, where we have been, where we are coming from, and generally what tho focus is and where we are going.

The areas that I feel we should be looking at and focusing on in Canada may sound like the first part of a two part presentation; because, really, speaking as the Representative of a Manufacturer, we think that to do a lot of testing is extremely expensive and often not very productive. So we tend to lean in the early stages to the analytic method.

Therefore, I think an area we have developed some expertise in Canada and that might usefully be expanded, is generally the area of the predictive methods.

That, really, then sub-divides into two natural classes, one of which is of very much interest to me, and that is the high-wing. I think a lot of the data we have around has been developed, generated on low-wing. Fortuitously those airplanes were available, and a lot of the information comes from that.

There is a considerable difference between a low-wing aircraft and a high-wing aircraft, and, of course, many light aircraft are high-wing.

A second area where we have considerable expertise in Canada - and Rod will, I am sure, be expanding on this, because we have worked together on this over many years - is the composites.

We, at DeHavilland, have had some experience in the use of composites in what might be classed as a crash situation. We have leading edges on an airplane that is required to meet bird-strike requirements; and that was very much an ad hoc test and retest situation to get it right, and that is just not acceptable to us. So, the expanded analytic capability in predicting the behavior of composites under the dynamic environment is essential, as far as we are concerned.

Those are really the areas that I think we should focus on.

MR. TORCK: Thank you very much.

In the composites, you are suggesting, then, not a testing environment, but, in fact, in line with your earlier one, more predictive in its nature.

DR. CICCI: That is correct. Now, it will have to be substantiated with testing, but it will take a lot of it. But, essentially, it is analytic and predictive, yes.

MR. TORCK: I see. All right. Thank you very much.

You indicated that, perhaps, Dr. Tennyson might be following up.

DR. CICCI: The reason I indicated that is that we have worked more years than I care to say together on some efforts in crashworthiness, and those were generally the lines we chose to explore, and I am sure that Rod still feels it is worth exploring further.

MR. TORCK: All right.

Dr. Tennyson, you seem to be next on the list. If you would care to address the problem of focus for us?

DR. R. TENNYSON: (Director, Institute for Aerospace Studies, University of Toronto): Well, this may sound like a one-two punch here, but it was never intended that way. I had no idea what Fernando was going to say.

We have been in the crashworthiness business at our Institute for about ten years, so this is not a new ball game for us.

Over the years, based upon what we have read and what we have heard, and the interaction we have had with NASA and Transport Canada, one cannot argue with some of the suggestions made today - improved seat restraints, better energy absorbing seat structures. I think those are very important areas that need to be researched. I think great strides can be made by modest improvements in these categories. And they don't apply just to light aircraft and general aviation aircraft. Of course they propagate right through into the transport category of aircraft, which is, in fact, of prime importance to the aircraft manufacturing industry in this country. We don't make the general aviation light aircraft, but we do have a substantial industry at Canadair and DeHavilland.

I would like to go just a bit beyond the suggestions we have heard today. They are all good, and they are all high priority areas; and support essentially the two areas Dr. Cicci mentioned, because we have, over the years, in fact developed a good crash dynamic code in this country. It has not been used, because the user community has not been able to understand what the code can do.

Our code will compete one to one with Krash and Dycast.

We have tackled similar problems with comparable results, so it is not that we are trying to invent a new program, but we can, in fact, build on what we have already spent time and effort to accomplish.

In that regard, there is a big payoff in computational structural dynamics programming.

We have the computational capabilities in this country, and, as you probably well know, there is a big effort under way in computational fluid dynamic, the design of complete systems. We can do the same thing, of course, with the structural dynamics codes aircraft.

Now, what is the point of all that? Well, it is not to develop a set of brand new codes. We can make improvements in existing ones. But they can be used, for example, in analyzing retrofits, either for general aviation aircraft or transport category aircraft.

You can look at them to try and determine what the load spectrum is for analyzing the seat restraint system, and the loads going up through the floor structure into the seat.

You can do post-crash reconstruction by trying to determine what happened, and what were the loads that were imposed on that aircraft. Could the occupants have survived?

We already have a crash test facility in this country. Most of you have not seen it, but we have one in our Institute. And we have done a great deal of sub-structure testing. We could not, of course, compete by flying aircraft into the ground; since we do not have the available aircraft to draw on.

We have looked at substantial fuselage structures, of good size, and we have used them to validate the computer model; and, in that sense, you do need the testing base.

I would also add that I think the composite area, which was mentioned earlier, is a very important area. We are being faced with the certification of these new aircraft both from the U.S. and Europe, and they are coming out all-graphite for example. I don't think we have enough of a data base to understand what is going to happen to those aircraft in a crash situation.

So, again, I think we can at least play a co-operative role with NASA and the FAA in becoming involved. And the reason, again, is not just for crash applications, but this research activity has tremendous spinoff to the aircraft industry in this country, as well as other supporting industries.

Our knowledge base in composites, particularly how they respond under dynamic loading, is very scarce, and I think we have heard that, in fact, it was somewhat premature even from the FAA's prospective, to look at crashworthiness regulations for composite structures. I still feel that this is an area we could collaborate on.

So, if I had to prioritize - which is not a good word to use, but you hear it enough seat restraint systems and better energy absorption in seats are key areas where modest costs can lead to possibly big payoffs.

But looking further down the line developing a computational structural dynamics analysis capability, with a strong interest in composites are very important areas. And, again, when you have the analytical capability, and the computational power, it is not difficult to include composite structural elements in the analysis; to design modern structures and materials systems.

With that, I will conclude, Mr. Chairman.

MR. TORCK: Thank you very much, Dr. Tennyson. That was very interesting.

In the way you say seat restraint, initially, and then the energy absorption, as the areas where we might want to concentrate, by that do you mean actual research and development within this country in, perhaps, an NRC lab, or an NAE lab - that kind of thing? Is that what you mean, or...

DR. TENNYSON: In a collaborative mode. I think it has got to be a collaborative mode.

You pick your niche, but in a collaborative mode; and, again, when it comes to computer codes, at least a few years ago we could not get the DYECAST code. The U.S. would not release this code to Canada. In fact, we were refused admission to a NASA conference in which they were releasing one of the crash codes, because it was restrictive technology.

I am not saying that is the way it is now, but I'm saying we always have to keep in mind that we do have to establish our own expertise to a certain extent where we may, in fact be inhibited from acquiring that expertise off-shore; but, certainly in a collaborative mode in all these ventures.

MR. TORCK: In all of the things that you have identified, Doctor, the one thing that is of some concern to me is the retrofit approach. If you look at in the sense of retrofit, do your priorities remain the same?

DR. TENNYSON: I think retrofits are very important and they also can be handled in the testing mode as well as using computational code, if you are making a major change to the aircraft structure or configuration.

MR. TORCK: Thank you again; thank you very much.

All right. Now, will Mr. David Heakes - will come, as is normal, from Transport Canada; we are here to help you approach...

MR. DAVID HEAKES: (Chief Engineering, Airworthiness Branch, Transport Canada): Thank you, Jim.

That joke, very often has a mixed reception.

I wanted to make a few remarks before getting into the areas, where I feel we have a contribution to make in Canada and should do so, to just look at the regulatory situation in which we find ourselves in this country.

Some of the remarks concerning the regulatory situation are probably equally applicable to the scientific area of R & D.

We are, of course, tremendously concerned about the high rate of fatalities and serious injuries in small aircraft. I think it is fair to say we all feel we wish we had been able to, or had made it possible, to pay more continuous attention to this subject, than we have; and we certainly welcome the initiative that is being shown in the study and at the symposium and the followup action we expect, to put a continuous focus on the subject, as opposed to a sporadic interest which has been true in the past.

I was reminded of this the other day, going over some of the history, and particularly seeing some of the work by Dr. Tennyson, which has really been excellent work in the field of crash dynamics; and yet we, in Transport Canada, have only sporadically paid some attention, or perhaps, even more important, sporadically provided some funding - just another indication of the need to focus that we are trying to develop now, and, hopefully will - to keep things moving once we have decided in which direction we want to go.

In the regulatory area I have referred to, of course our interest in R & D is to assist us in determining both the technical feasibility and the cost/benefit potential of new design standards - and in this case, the area of crashworthiness.

We are very much aware of the cost in terms of human misery and economic loss; but we do have a number of factors which must be considered - some might be called constraints - which affect our freedom to introduce new standards. Some of these include the fact that the majority of small aircraft operating in Canada are designed and built in other countries, most particularly in the United States.

Another is that in Canada we have adopted the Federal Aviation Regulations as our airworthiness standards, with a limited number of additional Canadian airworthiness requirements.

So that in the field of airworthiness regulations, it is very important that we try to keep in step with our counterparts to the south and also on a broader scale, on a worldwide basis, so that we can maintain a situation of fairness and equity to manufacturers and operators, not only in our own country, but in others.

Now, I guess, finally in terms of what we are able to do with the limited resources available to us in terms of the scale of things, again from our friends to the South, so we must be selective in the areas in which we devote our efforts.

I think both in the regulatory and in the scientific R & D field, the answer is really the same; a close co-ordination of our efforts with those of the U.S. and other countries, and the identification, as has been suggested by many people, and is a theme of this symposium, of the gaps in the work being done in other areas, finding work that needs to be done, and identifying the capability of organizations and individuals in our country to fill those gaps.

One of the things I have observed over quite a few years in the aircraft business Canada, is that if we are able to develop a field of expertise which does fill the gap in the larger programs of the United States, we are rewarded by a tremendous volume and flow of information coming back in the other direction. But if we cannot provide that little bit, often we are cut off, as Rod pointed out, from access to that large volume, and it is important that we do a reasonable share of the work.

When it comes to identifying areas that I feel are important areas where I feel we have the capability, I have been pre-empted to some degree by previous panel members. An area I feel we have both the need and the capability - is in the crash dynamics work, particularly as related to composite materials, and, as has been already indicated, we have the capability and, I think, it deserves support.

The other area that we have to recognize as part of the Canadian aircraft environment, you might say, is that the large volume of the small aircraft in this country, and there are a lot of them - are rather old aircraft now; and nobody seems to be manufacturing very many new ones.

I suspect a lot of the operators of these small aircraft could not afford the new ones, even if they were available.

So we are going to have a large fleet of aircraft, many of which are already very old, getting older and dominating the Canadian Registry, to the point that, if we only concern ourselves with design standards for a new aircraft, we probably will not affect the accident outcome in this country for a long time to come.

So, I believe, the second, very important area that we should address, is the question of bringing older aircraft up to a higher standard, not necessarily as high as the new aircraft, but a higher standard within practical limits.

So that, I would say that crash dynamics as related to composites, and the addressing of the question of retroactive application of the standards to old aircraft, are two areas I would like to see given most attention.

MR. TORCK: Thank you very much.

Dr. Gerry Marsters, NAE is our next speaker. Gerry, as you know, has a long background in the function that I am currently engaged in, so he comes pretty well equipped, I hope, to identify some priorities for us. And with that little bit of advertising, Gerry, please launch.

DR. G.F. MARSTERS: (Director, National Aviation Aeronautical Establishment): Thank you very much.

Ladies and Gentlemen, Jim pointed out this morning, four points that were raised a couple of years ago, and when I look at these, they represented, from my part, a substantial level of ignorance; and I have waited until today to do very much about that level of ignorance. So I am not as well prepared as you might think.

Secondly, being the last on the panel means that the most important things have already been said, and I am not sure I am going to add very much.

I would also like to put out this disclaimer that the ideas that are contained in this statement are not based on extensive personal expertise, nor are they based on detailed careful program research.

Just to make sure you know what they are, they are based on a collection of personal observations, perceptions, which are coupled with a substantial measure of prejudice, and unleavened by rational argument and logical thought processes.

I was particularly struck this morning by the definite miss with which things have gone ahead with respect to seat restraints, and, in particular, the 26-g-16-g vertical and so on; and I did some quick calculations - and this is going to present some interesting design challenges to the people who are going to be designing the new aircraft to meet these standards. If, for example my calculations are right - and they have been done very quickly - to restrain a 200-pound occupant at 26-g's requires 5,200-pounds of force; and if you think of a 2,600-pound airplane, that means you have two places where you can pull on that airplane and accelerate it at 2-g. So there are going to be a lot of changes that go on in that structure, as you restrain that one 200-pounder; and if you happen to have four of them on board, you are going to accelerate the airplane in the same sense by a factor of four.

Some very interesting challenges lie ahead, and I can be quite certain in saying that with existing aircraft structures, those points are just not going to be found. We can upgrade, but we sure will not be able with existing aircraft structures to get to 26-g.

The other thing that struck me is that it seems to me - and this comes particularly from Gerry Walhout's presentation - it seems to me that we can make some very large gains, simply by requiring people to install and use the equipment that is presently not good enough. It is not even on-board. With the 9-g restraint, if installed and used, it would gain substantial benefit for us in terms of saving lives and reducing injuries.

I was struck by Mr.Chandler's remarks as well about side-facing seats. Lord! We have a bigger problem than that in this country. I was reading the General Aviation News from COPA just recently; we are still successfully prosecuting commercial operators in this country for flying airplanes for which there are not seats for all the passengers, let alone side-facing seats!

God, let's give them something to sit on, and some measure of strapping them in. That is still happening, in the list of cases before the Tribunal. In it's most recent list had at least one example of prosecutions where there were not enough seats to go around.

I believe that a simple program of promotion and education will go a long way towards reducing loss of life and injury in this country, and lets have seats for all on the aircraft that we use.

I guess, the main point of my talk relates to something that has been explored and touched by most everyone, and that has to do with composite materials. In my view, one of the most important things related to crashworthiness, is the absorption of energy during the deceleration process. I am not sure that simply a measure of peak-g is the only thing, but how that is integrated, what are the energy levels? What do you have to dissipate?

Metallic structures have been fairly efficient in the process of absorbing energy; single engine aircraft have had a nice engine upfront which runs interference for you, and as long as there is not a rock in the way, you are going to do fairly well. At 26-g I am not sure what is going to happen to all the rest of the pieces of the aircraft, and where they are going to go.

But for existing aircraft, the energy absorption is not bad; it can be improved, and we may be able to make minor changes in structures, to improve the energy absorption.

When we get to the composite materials, non-metallic composites, we have a whole new ball game. These are resins reinforced by fibres of some kind, and these typically, exhibit much improved strength-to-weight ratios, and allow the designer to design in strength in a direction in which he wants it, to tailor the strength in some way that he wants it; but on the negative side, these materials are, of course, very, very brittle; they don't yield very much, and when they fail, they fail catastrophically, they shatter, very much like taking this glass and throwing it up against the wall. They do not absorb large quantities of energy.

We still have the problem of dissipating the energy that is involved in the crash scenario, so that it will be a major challenge to our designers of aircraft for the future to be able to create light, strong, energy absorbing structures that protect the passengers in crew compartments. It is not clear to me exactly how that is going to go, but it does mean in my view, that there will be a need for substantial testing programs, to characterize the material that we have, to characterize the behavior of the materials and the way in which we use them, and to allow a data base which will permit validation of computer programs; and I fully support the numerical work that is being done, and has been done, by Dr. Rod Tennyson and others; this is tremendously important work: there needs to be testing, adequate testing to ensure that what you get out of the computer program bears some relationship to the behaviour of the material itself.

Non-metallic composite materials, they are of improved strength-to-weight and quality, nevertheless they suffer from some additional limitations and faults. At this point it has been difficult to ensure uniform quality levels in composite materials. It depends on who lays them out, where and under what circumstances, and we have high levels of variability in the material properties, and the design allowables at present make it difficult to effectively use the materials in primary structures.

Fundamental work in the testing and characterization of these materials in their preparation, manufacturer and subsequent use, is necessary.

One of the problems I do see, and have seen from where I sit now and where I have sat before, is that proprietary rights sometimes manifest themselves in delaying the process of evaluation testing and dissemination of the properties of materials. Here, I suppose, there is the possibility of intervention by neutral bodies, such as government bodies, may aid in accelerating the safe application of non-metallic composites.

Another problem, not minor, is the business of how do we inspect and maintain and repair these new composite structures. I believe that as we develop new aircraft with composites, the crashworthiness challenges are going to be more serious than they were in the past.

To very quickly summarize, in the crashworthiness of an aircraft, I believe there are a number of things we have to do. We have to protect the living space. If you are going to hold the guy in there, in spite of 26-g, you had better make sure there is nothing else in there with him, and nothing else gets in there with him. So you are going to have to build the aircraft so that, not only is the passenger protected, but the space that he occupies is protected.

Adequate restraint is clearly of the number one considerations. We must provide energy absorption to get rid of the energy of the crash. We must reduce to the greatest extent possible and prevent post-crash fire, and we must provide the opportunity for actual evacuation of the aircraft.

Mr. Chairman, I think that summarizes my thoughts on crashworthiness.

MR. TORCK: Thank you very much.

Ladies and Gentlemen, we have now heard from each of the panelists, for which I think you very much.

But before we get into the discussion period, it might be appropriate if we just took ourselves a five minute stretch break and came back in and picked up on the questioning of all panelists to examine, perhaps to the best of their considerations, or their commitment to their particular views. In that regard, I would ask that the members sitting along the back rows should open up and participate as well; we don't want to keep it all just to the group at the table.

MR. TORCK: Before we get into the actual panel discussion, or the questioning of the panel, it has been suggested that Mr. James Dougherty of the General Aviation Manufacturers Association might bring us up to date on some of the more recent activities that are going on out there in general aviation manufacturing, so that it can put, if you wish, a base line on some of the comments made this afternoon by our panelists as to the direction we might pursue. Some of them may in fact may have been already looked at, but if I may call on Mr. Dougherty to favor us with a few remarks?

JAMES DOUGHERTY (General Aviation Manufacturers Association): Thank you, Mr. Chairman. Let me say at the outset that many of the recommendations of the previous speakers I certainly support.

But there are a few other areas, of interest to the group that GAMA is dealing with, both from a company standardization point of view as well as interfacing with our friends in the FAA.

We are supportive of the GASP-1 and GASP-2 activities discussed earlier today.

A difference exists in the FAR 23.1309 rules and the transport category requirements of FAR 25.1309. Both relate to system design but the FAR 25 rules are more stringent and contain specific provisions regarding system reliability not covered in FAR 23. GAMA proposed, at the Annual Airworthiness Review in October 1984, that a firmer basis for system approvals incorporating the system reliability concept be developed for FAR 23. In the absence of this, the FAA either has adopted some of the provisions of FAR 25 which we believe are too restrictive, or have resorted to special airworthiness conditions. Several advisory circulars that GAMA has worked on with the government relate to the proposed requirement; one in particular deals with autopilot installations which cannot be issued until the rule is revised.

In another area, FAA has brought to our attention that it is updating some of the data currently presented in the AFS-120 report on wing fatigue. The basis for adjustment is the reduction of an additional 7,000 hours of NASA Vgh data has been analyzed under an FAA contract. There is a joint industry/government effort currently under way to rationalize the findings of this effort.

The configuration issue - that is an interesting one. Mention has been made of composite construction including reference to the Starship. This has a forward wing and with it comes some rather interesting loading conditions. These type of loading conditions have been the subject of discussion between the industry and the government and are reflected in a forthcoming NPRM to be issued by the FAA. One thing recently alluded to by Dr. Marsters is the old age aircraft problem - there is a group currently at work within GAMA assessing what is termed continued aircraft airworthiness.

It is of interest to note that out of a population of some 200,000 general aviation aircraft, about 85,000 are single engine aircraft and that this group has an age centroid of approximately 20 years. It is recognized that an economic problem exists in terms of maintenance of older aircraft but also a need to provide the highest degree of safety possible. Recognizing these aspects, the companies believe something more could be done in the area of inspection. A program is being studied to treat this situation. It is primarily company oriented, with GAMA being the catalyst. Since the individual companies know their products best, they are developing supplemental inspection documents in various forms for use by the owners and operators. The term "supplemental" has been selected as it would encompass other parts of the aircraft, rather than just the structure. The program may encompass making recommendations to the FAA for rules revisions.

The GAMA companies have worked very closely with the government on icing certification for general aviation airplanes. AC 23-1419-1, 9/2/86, now exists which outlines the process and deals with icing certification.

Likewise, the Flight Test Handbook, which many of you are familiar with, has been totally revised for general aviation and recently issued as AC 23-8, 10/20/87.

There no doubt will be increased emphasis in the future, based upon Notices of Proposed Rulemaking on the use of CVRs and FDRs. The companies are taking a close look at that topic to determine the extent that installation of such technical equipment could be done.

Mention has been made earlier about composites. This is one issue that needs special emphasis. My personal view is that the main issue is quality control. Do you, or do you not, have a good bond? I can assure you that the steps one of our companies has had to go through in order to satisfy this to the FAA has been very expensive. I am not critical of this as we are in an area of concern wherein extensive service experience does not really exist. The research efforts that have been made in this field should be accelerated - the developing of new methods of inspection and techniques, and more rapid methods to do this. Coupled with this should be an indication of the extent to which you should reinspect, assuming deterioration, or degradation, or degeneration of some form or another that may take place in the composite structure.

Thank you Mr. Chairman.

OPEN DISCUSSION

MR. TORCK: Thank you very much, Mr. Dougherty.

At this stage, if we can open the floor - open the panelists, I guess, to questions from the floor.

I would prefer it, if you can, to direct your questions to the specific panelist, and if you cannot, direct it to me, and then we will see if we can farm it out and look for an answer.

And, panelists, I would ask you to volunteer, where you can, to help speed it along and to pick up on the questions.

I can go through and give you a quick rundown: Mr. Hayman, restraints, design of seats, ELT's, material characteristics; Mr. Tankesley, about eleven of them, but over water operations, water entry, that kind of thing, and a new and interesting one, the RF interference problem, new fuels, all composites; Dr. Cicci, analytic methods, predictive analysis, high-wing composites; Dr. Tennyson, analytic computation, dynamics, structural dynamics, and his priorities with seat restraint, energy absorption, computational structures analysis, collaborative effort and retrofit; David Heakes, crash dynamic, composite materials, and addressed the question of geriatrics; Dr. Gerry Marsters, protect the living space, passenger, pilot, energy absorption, post-crash fires; we should not look down our noses at 9-g restraint, and testing programs to validate computer programs.

That is a quick rundown of the areas that people picked, and you can identify some common areas in that area.

At this stage I throw it open to questions.

Mr. Peppler.

MR. WILLIAM PEPPLER (Manager, Canadian Owners and Pilots' Association): Thank you, Mr. Chairman.

Just for our American friends, I would like to say that the organization that I represent is the Canadian counterpart of AOPA, and this may be the only chance I may have to say a few words, Mr. Chairman, and I would like to say that I congratulate you and all concerned for the excellent symposium, because it has been very worthwhile, and I hope it will not be the last, and may be we will have more of these every year. It will be a good idea, thank you.

Now, Mr. Chairman, I would like to address my comments to David Heakes.

I go on to say that thousands of the 24,000 general aviation aircraft operators across Canada have already received the message that has been preached here today as it concerns the importance of wearing shoulder harnesses to prevent injuries should an accident occur.

The difficulty we are experiencing in fulfilling these various air safety recommendations, all boil down to two main problems. These are, first, where does one go to obtain a retrofit shoulder harness installation, that is DOT-FAA approved for the thousands of older Beech, Cessna and Piper aircraft that comprise about 90% of Canada's GA fleet of aircraft? The answer to this question is simply: don't know.

There are no reputable suppliers of pilot restraint systems that are advertising retrofit installations of approved shoulder harness for most of Canadian GA aircraft.

The second question pertains to DOT approval of a so-called one-off approval. If every GA aircraft owner in Canada could have heard the excellent presentations here this morning, I am sure they would be gung-ho to find ways and means of installing a shoulder harness in their own aircraft.

The obstacles that confront them in this regard are formidable. First of all, they will likely discuss the matter with their friendly AME - to our U.S. friends, that is your AMP mechanic - and he will be told that the installation may constitute a major modification to the aircraft, and a $100.00 fee must be paid to the regional DOT aeronautical engineer, along with drawings of the installation, showing pick up attachment points in the cabin, type of quick release harness, type of webbing used, etc. etc.

Where does one find a drawing of a shoulder harness installation to copy?

We talk about old metal aircraft -aircraft that is steel-tube construction, and fabric wooden aircraft and composite aircraft. But by the time the aircraft owner attempts to meet the shoulder harness recommendations, he is frustrated and discouraged before he gets started, simply because the answer to these essential questions is difficult to obtain.

There is a likelihood that if a source of information is found that the product liability concern will rear its ugly head and probably further frustrate the aircraft owners from fulfilling the recommendations made here today.

The best way to solve this dilemma, is for the Director of Airworthiness for Transport Canada, to approve several bare-bones shoulder harness restraint systems that would be designed to be adaptable to fit various types and models of Canadian aircraft.

If such a system were available today, by complying with the ready-made DOT approved drawings that DOT would make available for the asking, then I could safely say that hundreds, if not thousands of Canadian light plane operators, would take steps to install shoulder harnesses in their own aircraft.

What makes the "do" or "not do" difference is having the information readily available which enables the aircraft owner to predetermine that, by following laid-down instructions, that he has available to him, will enable him to have installed a shoulder harness that will be DOT approved and the cost of which can be calculated in advance.

Thank you.

MR. TORCK: Thank you, Mr. Peppler. I am glad that was a question and not a statement.

Dave, would you like to try that one, please?

MR. HEAKES: In some ways I think you anticipated me by providing an answer to your question.

First of all, you asked, where does one go? I don't know. I have to say that is the situation right now, and I agree that will be very difficult.

I also agree that the 22,000 one-off approval, while it would be good for revenue, is not very practicable as a solution, and certainly not a good one for the owner.

In highlighting this as an area requiring - we are talking about R & D - it really requires considerable work beyond the areas of scientific R & D to really develop the question or the answers to the questions you have posed, and to see if we cannot through co-operative efforts, develop possibly kits that would be, as you say, pre-approved for installation in particular models of aircraft.

I think that is an area which does need a lot of work, because we don't have the answers now; and I would propose that as part of the continuous program, that this work package be undertaken to try and achieve what you have said is essential and regularly available, hopefully, inexpensive kits could be installed with the knowledge that they are already approved.

MR. TORCK: Thank you very much, Dave for a very comprehensive response.

MR. WALTER McLEISH (Aerodevco): During the research that we did of the report we came across the information that Cessna and Beech and Piper all have kits for airplanes that they produce shoulder harnesses, and they have all been approved, and that is through their own approval process, which has been delegated to them by FAA. But they are expensive, and that would be one objection to them. But they do exist, and I think that it behooves somebody to look into what is available as a first move.

MR. TORCK: Thank you very much for your comment. That is a good approach.

Any questions?

MR. SOLTIS: I would like to make a comment with respect to Dr. Tennyson's and Dr. Cicci's presentations. It concerns computer codes. I very much support their thoughts. I would like to invite another area of thought and I think that some of the crash dynamic computer codes that we have today are very much comparable to the state that the NASTRAN computer code was twenty years ago. They were used by some specialists in research; they are used somewhat in a very limited sense in some early design studies, but not at all for certification.

Today, NASTRAN is used for certification and is readily accepted in most cases.

I think the current codes which are available for crash dynamics are somewhat complex and are used by a very select group of users and there does not seem to be much growth in that area as far as the number of users.

But we have this tendency in the FAA to want to add more features to the existing codes and some of the codes we have - I know every year there is a proposal for increasing the application, or bells and whistles available to those codes. But we don't seem to have any users of those codes, and I am trying to foster increasing the growth and usage.

I think we need to stimulate an increased user base if we want to make real progress in this area. The area I am talking about is improving crash-survivability.

One way of doing that I think may be - it could be time for a new minimal capability code which might be capable of being used on advanced PC systems, instead of the large machine requirement.

Not everybody has access to a large machine. Almost everybody now has access to a PC system. I think it would make the codes available to a much larger user group and provide a means of being a training tool to increase the user group itself and people would be familiar with the code and could expand to the larger and more complex codes more readily; and they can be used to run some parametrical studies on some simplified models, and minimize the runs necessary with the large codes with the bigger machines.

So my thought is that I would like to have consideration given to producing a code which might be acceptable for use on some of the new advanced PC systems.

DR. ROD TENNYSON: I think that is a good idea. One of the problems we found was to what extent can we simplify the code and still get data out or predictions out that bear any correlation with we observed in a rather complex model test.

That involved rather complicated numerical algorithms. I guess if I think of using a work station - come down, maybe, to the work station level, I think we can do that.

The challenge will then be to see if you could get it to the point where this minimal code, simplified model was accurate enough.

I guess where it really hurts is trying to get the G-load, and if you are willing to sacrifice something on the G-loads to go for, maybe, maximum deformation, transient deformations, that is easier to do; but it was trying to get the G-loads with the correct filtering that seems to take up much of our computational power.

DR. CICCI: Yes, I agree completely that in order for the end product, which is something that will be used quite extensively, I think it is absolutely essentially that it be simplified to the point where the average analyst, the average designer can do his parametrical studies and optimisations without having to know, first of all, a lot of computer technology, and, secondly, a lot of dynamics, or even structures, for that matter.

It must be simplified into a very user-friendly tool.

I agree with Rod that the real problem with that is trying to decide how simply to make it and how best to simply it and what to leave out, because it is implicit in the simplification that things will be left out, more assumptions will have to be made, and more prejudgments will have to be made, and I think, as an objective, it is certainly worthwhile, and we should be striving in that direction. I am not sure just how close we are to being ready to be able to do that, given that we are only now - you mentioned NASTRAN, and there are half a dozen others, static and dynamic finite element codes around that are just now becoming available for use on small machines. But it is certainly something that we should be striving towards.

MR. JIM HENRY (Canadair): We are heavy users of NASTRAN on intact dynamics.

We use NASTRAN for landing impact, and we use it for store clearance.

The reason that we have not used those routines in NASTRAN for seat restraint problems is simply because there is no requirement to do so. There is no requirement to do non-linear analysis on seat restraints, and that is the reason we don't do it. It is as simple as that.

MR. TORCK: Thank you very much. Did you have anyone that you wanted to direct that comment to, or are you looking for a response of some sort?

MR. HENRY: I was looking, maybe, for a general response, possibly from Dave Heakes.

MR. TORCK: Mr. Heakes?

MR. HEAKES: The response will definitely have to be very general, because I am certainly not an expert in the field.

But, I might comment, Jim, that while the requirements are not there, it can certainly be considered to be under-development, and perhaps some undertaking to learn in this field and to do some perhaps original development work might be useful, although not at this moment - it is not at this moment required.

MR. HENRY: Thank you.

MR. TORCK: Thank you.

MR. CHRIS HEINTZ (Zen-Air): I am Chris Heintz from Zen-Air, and I represent the small airplanes here.

We have built about 400 of them - 150 flying in this country, 150 flying in the United States, and another 100 elsewhere.

I would like to make, first, a comment. After a symposium like this, we go home and we are all fired up, and I think, we should keep in mind, as somebody mentioned very wisely, that the ultimate goal of crashworthiness is not necessarily to eliminate every crash, but to reduce the severity of the injury.

So we should keep that in mind whatever we do, because, otherwise all we do is take the poor people who fly the airplanes, and put them in a box full of foam all around them to carry them from here to Los Angeles or where ever, and they would not enjoy flying anymore.

Now, the light airplanes are here to be enjoyed and to fly them, and we have to be reasonable, and never forget the human beings who are the pilot, the passengers - not just to protect them when something bad happens, but also to keep his environment reasonably good, so that he has good visibility and has good movement.

Now, most of the things we have been talking about mainly applied to retrofit, because right now there are no light airplanes, no small airplanes manufactured.

So when we talk retrofit, nobody answers the questions of how about reliability. Now I don't know to whom I should address it, because we are here in an R & D environment and nobody gives a damn about them.

But practically, when we go out in everyday life with two days' legal environment, that is a very, very important question.

I would not dare today put on the market a shoulder harness, even approved by DOT and the FAA, simply because I would be scared that I would lose my business, if there is a crash and for some reason the crash exceeds whatever G-loads or energy absorption was prescribed, and the system fails.

So what do we do about that?

If you want to help to prevent the severity of the injuries, you really have to find a solution from the legal standpoint.

Another point which I think is very important, as a designer of both low-wing and high-wing airplanes, is the aspect of crashworthiness is very, very different from one to another - and that has not been highlighted at all. The question was mentioned, and I think a lot has to be done here.

A very interesting part in that whole diagram which was shown where you had the angle of impact and the speeds, most of those points, where they had accidents, hinged around a speed of 40 up to 70 miles an hour. Now that makes sense considering the present regulations which limit the stall speed for small airplanes - I think it is 61 knots or something like that; and most designers build their airplanes to those speeds.

But what about very slow flying airplanes?

So when we talk about G-loadings for the restraints and energy absorption, we have to have more data relating them to the impact speed; and that would be very helpful for designers. In order to design more crashworthy structures on one side, and the structure again is related to the restraint of the occupants, because if most of the energy is already dissipated by the structure, there is not that much you have to take if it happens to you.

So I would like to put that as an input for further research and development.

Thank you.

MR. TORCK: Thank you very much.

MR. DEREK FERGUSON (Program Manager, Transport Canada): I have a question that relates to Ron Hayman's comment on post-crash survivability and ELT's.

I am not really sure whom it should be directed to. Maybe I will direct it to the Panel.

I believe Transport Canada has had a working group on ELT's, and I was wondering if that group has finished their work, and, if so, what were the findings, and is there a possibility that this is an area where some research and development should be directed.

MR. TORCK: If I recall correctly, the effort is to improve the reliability of the ELT in the sense of making sure that it goes off when it is supposed to go off and not to go off when it is not supposed to go off. I do believe the work has concluded, but I may be in correct on that. I see that I may be getting some help from over there...

MR. J. P. STEWART (Acting Director, Aviation Safety, Transport Canada): I am Chairman of the working group. The work is now concluded, and you are quite right that part of the study is to increase the reliability, but part of the study as well is to increase the crashworthiness of the ELT in particular, and particularly the antenna, which always seems to pull away.

Just the other day, yesterday, in fact, we did have a meeting and made a number of decisions to proceed, and we are working with the Transportation Development Centre.

As many of you know, we have surveyed industry and the users of the system, so that work is ongoing right now.

There is also - part of that study is investigating the use of 406 megahertz, but it certainly has not been completed as yet.

MR. TORCK: Yes, Mr. Soltis?

MR. SOLTIS: Steve Soltis, FAA; I am not sure if this is the same program, but the FAA also has an ongoing program with ELT's that is being sponsored in our Washington office. They have been evaluating the adequacy of the current ELT pulse and the g switch, so to speak, and there is a new g switch post in the latest revision of the ELT, and we have looked at that, and it is a more reasonable post than in the older systems.

We are also looking at maintenance and ways of inspecting ELT's and eliminating many of the problems associated with the batteries, and we are looking at the possibility of retrofitting the airplanes with, maybe, ELT's certified to the new TSO.

We are also looking at the possibility of doing some more investigative studies in the field with aircraft with new ELT to see how their performance compares with the past performance of ELT certified under the new TSO.

So if this is not the same program, I would suggest that you might want to contact our Washington office, and maybe Art Hayes may bring a message back for you, and to key in and find out what are people are doing back there.

MR. STEWART: Are you talking about the TSO C-91, the work that is being done there? **MR. SOLTIS:** Yes.

MR. STEWART: We are well aware of that.

MR. CHANDLER: Supplementing what Steve has indicated, the FAA did approach the RTCA, and they had a special sub-committee at work developing revisions to the specification that relates to the ELT. I think the chap's name is Thompson at NASA, who has been the Chairman of that sub-committee. They have finished their work, to my knowledge, and that is what has been fed back in some report form to the FAA for incorporation and an updated TSO.

SHAWN O'REILLY (Transport Canada): I'm Shawn O'Reilly from Transport Canada, and I have a question to the panel, and, possibly, to Mr. Tankesley.

Most of you have addressed restraint systems of one form or another, but none of you have addressed restraint systems for infants. I know a little bit of work is going on from the direction of automobile infant restraint seats. But has there been any work or any thrust on that particularly for small aircraft, or even larger aircraft? There aren't any restraint systems required now, so is there any movement in that direction, or have there been any thoughts on it, or work on it?

MR. HAYMAN: All I can say in this respect is that I fly often with my young grandchild, and I take my seat from the car, an approved DOT car seat, and I use the seat harness in the aircraft to strap it in. And that is the best I can do.

MR. CHANDLER: There is a continuing problem with child restraint. As of the present time, the approved automotive seat passed February of 1985 I believe are acceptable for use on board transport, and, inherently, GA-type airplanes.

The problem with using those seats is that a passenger seat must also be available, either by purchasing it or by gratuitous kindness of the airline you're flying on.

But the alternative of having a lap child restraint - a child restrained in your lap by some approved and functioning restraint system, has not been resolved, and, as far as I know, there is no strong effort to do so.

One of the problems with that approach is the possibility of having two federally approved child restraint technologies in existence at the same time - co-existing, one that would be good for automobiles and airplanes, and one that would be good for airplanes only, running the risk of perhaps the "airplane only system" would work its way to automobiles and end up injuring more children than it might be saving in airplanes.

So I don't see a great deal of interest in moving towards a lap child restraint system.

MR. TORCK: Thank you very much.

Mr. McLeish?

MR. McLEISH: This question of child restraint depends upon whether you are talking about infants or children.

I think the present practice of the air carrier is to provide a small cot fastened to the structure for infants - has potential to be developed to provide safety for the infant during a crashworthiness situation. I do not believe that has been explored.

With respect to children that need to be strapped in, the age changeover is at age two. By the time a child is two years of age, that child is imperilled to be put into a seat, because the parents are obliged to pay for a seat for a two year old, because the present system of lapping, or using a lap belt, is not good for the child; and so there needs to be work done in that area in both large and small airplanes.

Like my counterpart from the CASB, I have been flying a small airplane, I have been flying a small airplane with small children, using the conventional car seat, which works very well; but while it works for small airplanes, I think the question you opposing with respect to transport category aircraft has been well-described, except that I think there are a couple of areas which could be explored.

MR. TORCK: Thank you very much, Mr. McLeish.

Are there any more questions for the Panel?

MR. JIM WHITE (CASB): I would like to direct my question to Mr. Tankesley, and explore the issue of over water flight - more specifically, float planes. We have a large number of float aircraft in this country; in fact about 25% of all aviation fatalities in this country are caused to float planes. The failure rate is about 18%, which, again, is about 50% higher than the general population.

Granted, about half of those take place in the water; the rest are planes that crash on land.

The problems of crashworthiness or even survivability in a float plane are different from an aircraft that crashes on land. I am wondering if you can tell me if there has been any work done, or any consideration given to that aspect of float operations. I think the real problem is egress from the float aircraft.

MR. TANKESLEY: We have had some problems in the past, but we have not done anything in the way of regulatory work.

Strangely enough, at one point we had a question which came up about what was the definition of a float; and we got one lawyer to provide that interpretation, which I questioned, because that interpretation turned out to be that if the thing turned upside down, you can see the bottom keel of the float, it was still afloat. I said that does not provide much safety.

We have got a different interpretation from counsel about that, but we still have not done anything in the way of regulations, and what I find is that in going back and looking at the old CAR three's, and the involvement of the regulations in this area, it has not been handled very well over the past years. It has been done more by a "well this is the way we do it". The float manufacturer says, "I know how we do it" and the FAA has more or less let him do it the way he has been doing it; and there have been questions about, "What are the floatation requirements, and how many compartments can you actually flood," etc.

Quite frankly, it has not been part of our real priority, and we have not done much in this area whatsoever. But it may be an area we need to look at more than we have paid attention to.

MELL WALKER: This problem has been around for about forty years now, and all of us are probably very familiar - reference was made I believe in an earlier presentation, but ever since the original Royal Airforce statistics were put up in the forties and fifties, we shyed away from the issue of rearward facing seats. It is a complex issue, and the issue has more to do with institutional factors than engineering factors.

My own personal involvement is that 13 of my friends are alive today after being in an airplane that crashed upside down at approximately 150 knots. They were in rearward facing seats, well designed seats, well anchored seats; and when the Argus went in at Summerside, when the plane front went through the airplane, 13 of them managed to crawl out, and the pilot, who, of course, was facing forward, climbed out, and they were wearing a very well designed harness.

And we tend to shy away from it simply because the carrier says the public wouldn't accept it.

But I would like to make an analogy here to Transport Canada's Road Safety Branch, which, for about 20 years, worked towards what has finally happened, which is now that across Canada we have seat belt legislation in place in all the provinces. The research there had nothing to do with technology; it had everything to do with assembling those necessary arguments to make the case for appropriate regulation.

Regular the arguments eventually turned out well, whether it is necessary or it is not necessary, I think it is a necessary and worthwhile thing to look at.

I look back over the last five years: Japan Airlines 123, Delta 191 going into Fortworth, the recent DC-9 crash at Stapleton; and you can go back and estimate that roughly half of those people would be alive today if they were sat in properly designed and properly anchored rearward facing seats.

So I would just like to raise that as an issue, as one worthy of looking at, and, by the way, having flown about 3,600 hours in my life sideways in an Argus, sideways in a Hercules, sideways in a Buffalo, sideways in a DC-3, I heartily endorse the fact that anything we can do to get rid of sideway seats would be very worth while.

MR. TORCK: Thank you very much for that comment.

Ladies and Gentlemen, we have hit the time for a coffee break, and before we do, I would like to offer your thanks and my own particularly to the members of the panel for, first of all, their presentations earlier on, and for their statements in response to your questions. I think it has been a very good effort, and I thank you most sincerely.

SYNOPSIS

MR. TORCK: We have reached that part of the day where we have asked our more senior members of the organizations involved to provide us with a synopsis.

Once again, I am asking as moderator, so my task is relatively straightforward: simply to introduce those individuals to provide a synopsis.

We had, originally, Mr. Claude LaFrance scheduled for this afternoon. He, unfortunately, has been called away earlier this morning, as you know. In his place this afternoon, we have asked - and he has agreed - Mr. Weldon Newton, Director General Aviation Regulation (my boss so I have to be very careful); he has agreed in fact to provide the synopsis.

We are also pressed for at least a departure from here to reach our place of work somewhat earlier, but I don't think you are going to run out on us right after the synopsis, are you, Mr. Newton?

MR. NEWTON: No, I have to leave at 5:00 so we are all right.

MR. TORCK: Mr. Robert Mayes, Director General, Research and Development, Transport Canada, will also be making a comment, involved, as he is, with the Development Centre.

Finally, Mr. Earl Dudgeon, Vice President of Engineering for the National Research Council will also be providing a synopsis.

With those brief introductions - most of the information is available in the handout - I will call now on Mr. Weldon Newton, our Director General Aviation Regulation, to make his comment.

MR. WELDON NEWTON (Director General Aviation Regulation, Transport Canada): Thank you, Jim, Mr. Moderator.

Ladies and Gentlemen, on behalf of Transport Canada, Aviation Group, I would like to express my thanks for being invited to join with you today, and also add to the remarks of earlier speakers in congratulating the organizers for the symposium.

I think it has been an excellent program, very relevant, and the speakers have been superb.

Being the Director General of Aviation Regulation, the focal point of what I do (and my staff) is developing regulations.

As such, we are not directly involved in R & D activity. But part of the regulation making process presumes that the regulations that you are going to enact are backed up, in many cases by strong R & D activity.

More and more in this era of regulation, those that are regulated want to know why. You have to justify, you have to be prepared to put the cost benefit and the analysis on the table; I think that is fair, a reasonable expectation for the industry and the public to have of us.

I think that as a result of today's presentation - and in my mind I came to the presentation perhaps with much more embryonic knowledge than of a lot of you who have assembled here today. And I am leaving with a very strong feeling that crashworthiness regulation and educational programs are important in reducing death and injury following accidents. That came out very clear today, certainly for me.

In the past, in the Transport Canada Aviation Group, we have sought candidates for R & D activity in the aviation mode. This year, 1988-89, this symposium is very timely, very opportune, because one of the reasons I have to leave at 5:00 is because I am going away for a two-day strategic planning retreat; and the purpose of the retreat is to identify some of the key issues and concerns that are facing my organization for which I have to have a strategic response, a direction; and the timing is perfect, because obviously Jim and I will be going into the huddle in the next day or so, and fresh in our minds will be this symposium, and you may rest assured it will occupy its place in the dialogue of my directorate.

I think it is important not to let these gatherings go unaction, and it is going to be very important to pick up on the momentum generated by this symposium, which was, in turn generated by the Sypher:Mueller study, which I reviewed again last night and found to be a very interesting and informative document.

I think it is going to be very important, walking out of here, to ensure that the dialogue does not end here, and that there will be a process by which we can get together and identify, in a collective sense, the areas of crashworthiness R & D that might be pursued, certainly in the Canadian interest.

In that connection, certainly it never ceases to amaze me that when I meet with our FAA counterpart, the commonality of interest that we have in many, many areas; and I look also to close collaboration with our American counterparts in perhaps pursuing and identifying some of the key initiatives that we should be pursuing in the months, perhaps years ahead.

Rather than trying to pick an order of priority, the initiatives which might be more appropriate to pursue, I am going to cop out on that, and propose, perhaps instead that we in government and Canadian industry develop a standing committee of all interested parties; and I think that this committee should be an advisory committee on the most appropriate topics to pursue in the area of R & D crashworthiness.

I am aware that funding, certainly from government, is a problem - certainly within the Aviation Group and Aviation Regulation is a problem. We do not have the availability and the ready access to funds that we once had.

Maybe Bob Mayes can speak a little bit to the funding, because, obviously these initiatives are not without cost.

I think at this point in time I have perhaps said what I wanted to say. I have been specifically general as opposed to trying to pick specific issues that we should have as number one on our hit list.

But, in closing, I would like to reiterate my thanks for being asked to provide the summation I have provided.

Thank you.

MR. TORCK: The next one to provide the input is Mr. Robert Mayes, if you would, sir?

MR. ROBERT MAYES (Director General, Research and Development, Transport Canada): Thank you very much, sir.

My points are grouped into three types. Overall comments to begin with, some specific comments on the discussions I have heard today, and finally, very brief conclusions.

Going back a little bit, I found, as I reviewed our R & D program in Transport Canada, we have been very light on the issue of crashworthiness. In fact, apart from some work by Dr. Tennyson in the late seventies and early eighties on light aircraft structures, there was a definite hiatus until the Sypher:Mueller report.

I presume that is because it was of low perceived priority, coupled with the fact that we were, at the time, faced with shrinking R & D budgets.

Nevertheless, I certainly feel that this is the beginning of a new era today, and I am certainly pleased to participate in this seminar. I hope we will re-examine the perception that crashworthiness is not a priority for us.

I hope the outcome will be a well-developed rationale for an agreed R & D program.

Another aspect of this seminar is important. There was the building of collaborative efforts in many ways - not only between the R & D group and the airworthiness group in Transport Canada but also between Transport and the National Research Council of Canada, and also between the Government of Canada and U.S. Federal Government Agencies. With respect to the latter, I would like to thank them most sincerely for their presence here today and the most generous and open-handed way they have shared data and findings with us.

I would just like to say parenthetically that we do have a long-standing co-operative R & D agreement with the U.S. DOT and its agencies, and not only in the aviation field, but also in the rail, marine and automotive fields - we have a very positive track record there. We look forward to the bi-annual review meeting in the Spring.

When this seminar was proposed, I agreed that we should proceed with it as a response to two key aspects of current government policy. First of all, with respect to transportation policy, it reinforces the overriding safety priority within the Department's operations, and also reaffirmed in the proclamation of the New Transportation Act this January; and then, secondly, with respect to the Government's science and technology policy. That policy recognizes that, in order to achieve effective and timely progress, we must harness the collective technical expertise in the country; not just expertise that resides in government scientists, engineers and technologists, but also that in the academic and business communities as well.

Consequently, I am very pleased that we have such a good showing from the University and industry sectors here today.

With respect to the specific presentations today, I have about half a dozen comments, if you will bear with me. The first is that I really enjoyed today. My professional background is in highway transportation, and I looked forward to today to learning something very specific about the issue of crashworthiness.

I also got a surprise. I was party to a number of discussions over the last ten to fifteen years on the issue of the use of harnesses in heavy duty trucks, and the integrity of the truck cab. We were always led to believe that those issues were solved years ago in the aviation sector. It was quite a surprise to find that is not the case! I don't feel quite as badly as I did this morning about where my experience placed me in the knowledge continuum.

With respect to R & D issues, I was very impressed with Mr. Chandler's presentation this morning on the continuous multi-year commitment that we have seen in the U.S. on this issue. On one of the slides he showed that work was started in 1971, there were significant findings over a 16 or 17 year period, cumulatively building an understanding of this field. I think that is a lesson that we, in Transport Canada, need to internalize.

We have just made a policy decision in the Department that we will reaffirm our commitment to technological R & D. I think that it is a tremendous decision. But I think we must also recognize that we need persistence, we need patience - and I don't really intend to make a pun but I think I must - we don't need "crash" programs with instant gratification.

We must recognize that if we put our hands to this particular plough, it will be sometime before we turn up useful results. Clearly, we have to make a fairly long term commitment to it, and I think, from a personal point of view, we should.

Turning again to Mr. Chandler's presentation this morning, he put up a slide to which he said that there was a lot of work remaining to be done. You could label that as a "research agenda", and I think that particular slide is something we should give very close scrutiny to as we follow up over the next few weeks on the results of this symposium.

There were also some interesting comments this morning about a general need not only for improved non-destructive testing techniques, but also increased use of computational methods - and that was echoed by several of the panelists in their comments this afternoon.

With respect to the general issue of post crash survivability, the ELT issue was mentioned several times. There is a need for a point of clarification where we stand on that particular topic.

I would like to emphasize that it has been agreed that the TDC will embark upon a multi-year program (jointly with the Aviation group) to improve ELT technology. In fact, it is the first multi-year program that we have identified under the new departmental R & D policy; undoubtedly our commitment to it is solid.

The second aspect of post-crash survivability, concerns the issue of over water operations. Certainly that is of potential interest to us here in Canada.

Another interesting point that came up in the panel discussion this afternoon - I certainly have not heard of it before - was the use of alternative transportation fuels in small aircraft, and particularly the use of automotive fuels. We are looking at the general issue of the safety of oxygenated fuels in automotive applications, principally M-100, and I am wondering whether we should expand that research to small aircraft. That is something we can certainly discuss further.

As I note the comments this morning by speakers and again by panelists this afternoon, the issue of composites keeps coming up over and over again - crashworthiness, the airframes, the energy absorption characteristics, the mechanical characteristics and the effect of lightning, and so on. There were several comments made reinforcing the idea that we need to expand our analytic, predictive capability with respect to these materials and it seems to me this is a fruitful area we should discuss further.

On the point of the need for co-ordinated efforts, and that we are the recipients in Canada of aircraft that are produced elsewhere, there is clearly a need to co-ordinate our work with the U.S. and with other countries. As I have already mentioned, we have an excellent co-operative regime with the U.S. - we also have them with the U.K., France, and the Federal Republic of Germany. We can invoke any or all of them to assist in this work. Having said this, we must bear in mind that in order to have a seat at the table and have a meaningful technical relationship, we must have active R & D of our own, and furthermore, it must be targeted to things that are important to us.

If you don't have a bargaining chip, you won't get a seat at the table, or you may get an on-lookers seat, I guess.

John Mew mentioned to me at lunch the (relatively modest) work we have done with respect to smoke masks over the last two or three years; we have not solved that problem by any means, but we have brought some very useful test results to bear, and, as a result of it, we are being treated as more than an equal partner in international standards development work. I think this topic of identifying unique issues is an important one. There certainly seems to be one with respect to the problems of retrofitting an aging fleet - again, that is something that we should look at in more detail.

By way of an overall summary comment, I can say that as a result of this seminar we, in the R & D directorate, see crashworthiness as an important aviation safety issue. It will certainly receive further scrutiny and support in developing a focused R & D program.

Finally, picking up a point that Weldon Newton made, developing the technical, underpinnings for regulation is a genuine, bona fide, aspect of our R & D work; there is no question about that in my mind. We are ready to work with the Aviation group to do this. Over the next few weeks, Bill McLaren and Barry Myers will be pursuing this issue so that will not be just this one day specially staged event to take the findings of the Sypher:Mueller report forward - instead, we will be developing a coordinated program.

Thank you.

MR. TORCK: Thank you very much.

If I may, I am particularly pleased at your recognition for the sustained requirement, this longer term push that seems to have been lacking over the last many years; and recognition of that alone is just terrific as a result of this particular seminar.

Thank you very much.

If I might now call on Mr. Earl Dudgeon for a comment?

MR. EARL DUDGEON (Vice President, Engineering, National Research Council): Thank you very much, Mr. Chairman.

Ladies and Gentlemen, the two speakers ahead of me in this panel have referred to this seminar today as being a learning experience for them. I can assure you that it is also a great learning experience for me, because I was starting from very, very low on the scale of knowledge about crashworthiness - what it all meant. In fact, I asked Gerry Marsters if he could brief me on this - give me a little course on this before I came to this session, and he said, "Not a hope; you haven't got time to learn it here." But he was wrong. Today has been a very good learning experience, and I think all of us have benefited from this session.

I would like to echo the comment of Bob Mayes about the fine representation from the United States, because they have done extensive work in this area in recent years, and they have provided us with a rapid course in the knowledge base that exist, and the direction we should go in the future.

In my comments, I would like to emphasize the research and development part of the title. What we have heard today summarizes a lot of Research and Development that has already been done. There is much useful R & D that is available, and is not being applied yet; it could be used to reduce the severe injuries and fatalities if it was widely used, possibly through education - more likely through responsible regulation.

Education itself is probably not enough. Education was not enough to ensure seatbelts were used in automobiles, regulations had to be enacted by Provinces in Canada. Perhaps it will be the same situation with improved crashworthiness in aircraft. I emphasize responsible regulation is required.

Nevertheless there is much research that can be done which will be useful. I thought, it would be useful to say a few words about the organization I come from - what the National Research Council is, especially for some of the Americans here today who may not know NRC. If you ask Gerry Marsters what the Nationals Research Council is, he would say it is part of the National Aeronautical Establishment - and sometimes I think he is right! But the NRC, the National Research Council, is a major Canadian institution, an agency that is concerned with the advancement of science and technology, particularly through the support of research and development.

NRC operates a national information system through our Canadian Institute for Scientific and Technical Information. It is a special depository of aeronautical information in Canada, a unique installation, and it is accessible across the country for more than 2,000 terminals for data acquisition.

The National Research Council also supports industrial research and development and technology transfer from all research groups in Canada - and I emphasized that because I will be coming back to mention later the importance of a co-ordinated or a collaborative program - I see Rod Tennyson has left, but I would like to support his statement that a Crashworthiness research program in Canada will have to be a distributed one, drawing on the resources that we have across the Country.

Last but not least, the National Research Council, operates national facilities and laboratories - wind tunnels, experimental aircraft, special test facilities and projects in materials and structures - aircraft structure. We do research and development in support of industrial and government priorities while the NRC actually has laboratories coast to coast, the aeronautical research is concentrated essentially in one division of the National Research Council. It is the "NA" part of NASA for Canada, the aeronautics part embodied in the National Aeronautical Establishment.

The current level of research that is aeronautically related is about 20 million dollars annually.

We do not have a discreet program in crashworthiness at the National Research Council at the moment. I was reminded by one of my colleagues that in 1982 he had proposed a program specifically in that field, which was aimed at enhancing our own capability and in support of Rod Tennyson and other groups in the country that had already demonstrated a competence and a commitment to that area. I guess, we ran into the lacuna at that time that Bob Mayes mentioned: there just weren't the resources around, the money was not found, and the program did not get supported.

But, perhaps, the climate has changed, and even though our resources seem still to be going down rather than up, perhaps it is time to have another look at this to see if we can re-order the priorities to address this important issue.

The National Research Council has activities going on in its laboratories that are related to crashworthiness and can contribute to it, particularly in the area of structures and materials. We are very active in advanced composites, particularly in the non-destructive testing area. This has been referred to several times as a particular problem with composite materials. It is not only that they are brittle and when they impact there is very little energy absorption, but you cannot tell reliably the quality of the structure that has been made. It is currently very difficult to measure structure quality by non-destructive methods.

This is a program that is of interest to the military, and while our work has been supported that way, it has impacts and spin-offs for the general aviation field, as, inevitably, the industry will be moving towards more advanced composite structures in the future.

Numerical analysis has been emphasized - computational dynamics for structures and fluid flows; this is a priority of the National Research Council in our laboratories for the future. We see that our National facilities - wind tunnels, structural testing, impact tests, will be used, not just as development tools, but more and more to verify computer models that can do the preliminary design sorting. This is a thrust for the future.

When you look at how to decide priorities for research and development, in any priorising of research and development needs, there are some criteria that you have to use that I think apply as well.

Firstly, are the objectives of the research clearly defined? You have to define what it is you are going after. Just to say that we would like to do research in crashworthiness is not good enough; we have to find a niche, we have to be specific; we just do not have the resources to cover the whole water front.

Secondly, has the research, which has been proposed, the potential to achieve the objective? We have to make enough of a commitment of resources to make sure that if we are going to start on a project, we can reach a useful objective. Again, I refer back to Bob Mayes comment about the sustaining nature of research and development. Starting and stopping tends to produce research that never gets translated into useful activities.

And, of course, there is the cost benefit analysis. Is the level of research appropriate for the benefits that you expect from the research. This is especially critical when your resources are very limited and you have to be selective.

Finally, especially for Canada, I think we have to be very careful in determining whether the research we are talking about doing is appropriate for Canada. We can not do everything that could be done. We have to select the kind of research that is appropriate to our situation. For example, we don't build general aviation aircraft in Canada to any extent.

Therefore, in selecting the research activity that we do, we should keep these factors in mind, and look for programs that counter-balance other activities, or perhaps have a spin-off for other areas. Someone else earlier mentioned the spin-off that would come from general research in composite materials applying to the kinds of aircrafts that DeHavillands, or that Canadair produce.

The National Research Council - National Aeronautics Establishment's potential role in Canada in R & D related crashworthiness activities, as emphasized in the Sypher:Mueller report, and we believe that this report has astutely summarized the current situation, and has proposed logical recommendations for future directions.

We concur that, because of the large use of aircraft in Canada, and the special operating environment that exists in Canada, such as the distances, the sparse population, and the climate extremes that we have, that Canada should make a contribution to international efforts aimed at improving crashworthiness of aircraft.

That leads to sharing. We just cannot sit back and rely upon other organizations, other countries, to do the research, and expect to benefit to the full from that activity.

To make the most effective use of the limited resources, Canada should identify the areas of primary Canadian interest. The niche areas. In the Sypher:Mueller report two areas were identified: the partial retrofit area (that's very logical) and post crash survival techniques; and we have talked about the possibility of studies of over water activities.

The report also pointed out that Canada has a special expertise. We have concentrated on advanced composites and computational structural techniques, and this can be a good contribution to such a program. The NRC has activities in these areas, and we would be pleased to contribute to a national or an international program in the area. But our resources at the moment are very stretched and too limited to make any contribution alone; and I think that applies to any single organization in Canada. We must build on our existing strengths, and this will require a co-ordinated program involving other centers of expertise across Canada. You have heard from Rod Tennyson and the very effective and competent group at the University of Toronto - and there are other groups that can contribute in other parts of the country. Together they could contribute to a significant defined program that is internationally focused.

Steps are already being taken to develop networking arrangements that would assist in implementing such a program. The National Research Council would support Transport Canada's interest in defining priorities and possible implementation procedures for a reasoned, co-operative Canadian program in crashworthiness.

Resources are always a problem, and I think particularly in Canada where our industry interest is limited because of the local market situation; but it is too important to pass up this opportunity.

Thank you, Mr. Chairman, for the opportunity to participate in this seminar.

MR. TORCK: Thank you very much.

Well, ladies and gentlemen, that brings us to the conclusion of the synopsis. I do not intend, in my role as moderator, to try and synopsize the synopses, if I may use the term.

Rather than do that, I would like to just step back briefly and remind you that when we opened up our discussions earlier this morning, one of the hopes that we expressed was that your participation would assist us, Transport Development Centre and Transport Canada, to achieve the goal, if I remember correctly, where we could move forward and develop a co-ordinated R & D program, between Government, Industry and Universities, that will not only contribute to enhanced safety in the area, but would lead to an improved joint R & D effort between Canada and the United States; and it seems to me that the efforts of the speakers this morning in laying the ground work and laying the baseline for us, the wise discussions and points of view expressed by our panelists, and then, finally, the concluding remarks in the synopsis efforts of the individuals who have just spoken - have done precisely that.

I look forward to working again with Bill McLaren of the TDC, and with the individuals from the FAA, who have come forward and offered their support to our efforts, indeed, in finally pulling this thing together and, indeed, getting ourselves pointed, turning that camel and pointing it in the right direction, if you wish; and I look very much forward to those efforts and working with the groups.

Finally, I would be very much remiss if I did not say to the Transport Development Centre, in particular Bill McLaren and Barry for your efforts - and I think you both personally for your efforts in trying to pull this together; and right at the very end, Sypher:Mueller, who assisted us so strongly, both in helping to point out the direction to us as a result of their studies, and their assistance here today: I think it has just been tremendous, pulling this package together; the results you have seen, the selection of the speakers has been in large measure through their efforts and knowledge in the area.

So I think we would be well advised to express our appreciation to that group in the traditional fashion.

Finally, Ladies and Gentlemen, if I may just simply wrap up with one big thank you very much, and good night and have a very good trip home.